Me 262s for Sale: Flyable and Ferocious

Space Tourists Tell All
(PAGE 46)

AIR&SPACE Smithsonian

Lighter Fighter

HOW THE JOINT STRIKE FIGHTER GOT SKINNY

Lockheed Martin F-35B >>>

The End of Air Traffic Control?

(p. 36)

The Maestros of Mission Control

Landing in Baghdad

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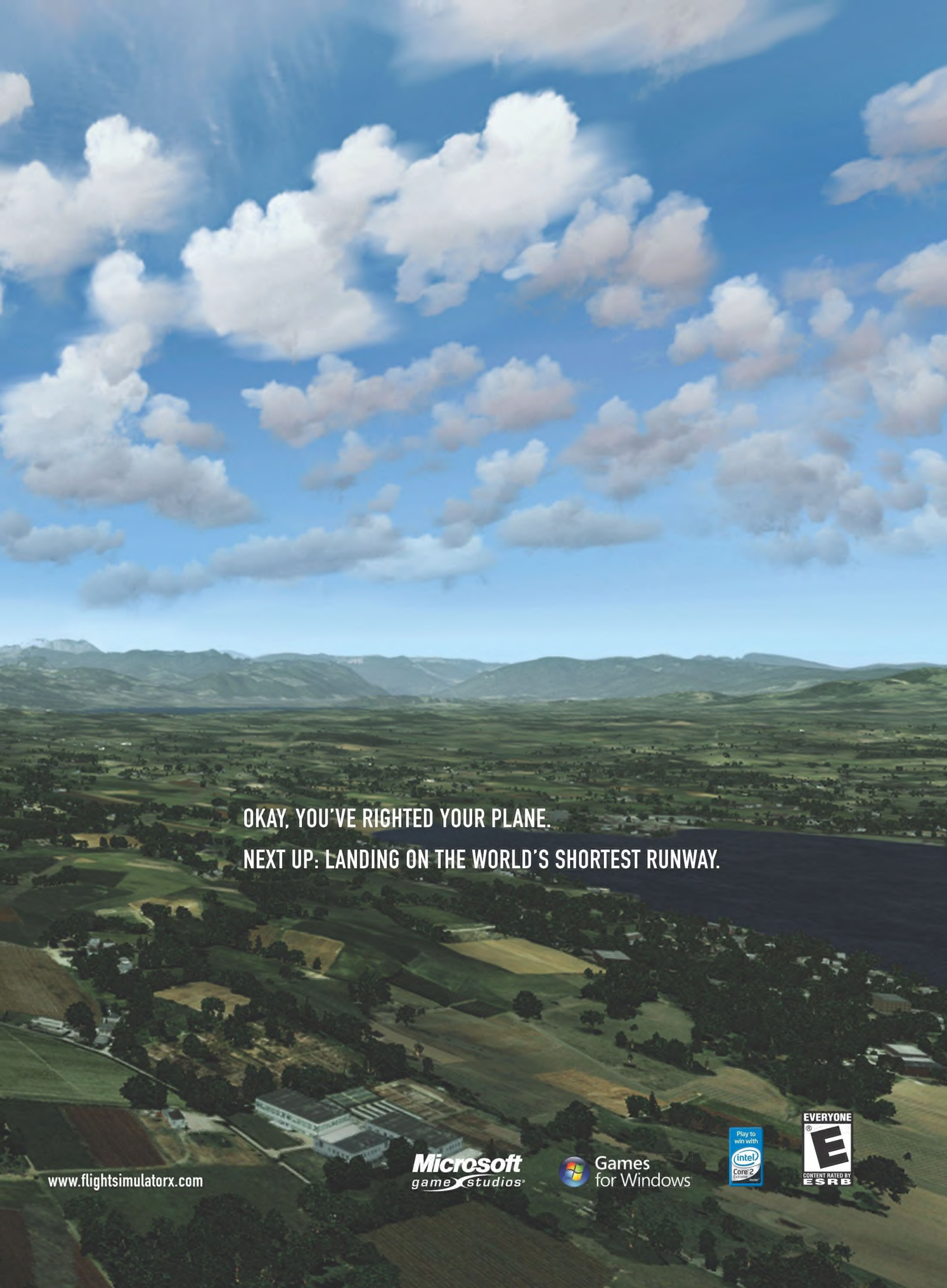
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(ACTUAL GAME SCREEN SHOT)

OCTOBER/NOVEMBER 2006 VOL. 21 NO. 4

AIR&SPACE Smithsonian

FEATURES

COVER: As any supermodel under spotlights would, the F-35 Lightning II put its best face forward for photographer Eric Schulzinger during its first public viewing last July in Fort Worth, Texas.

DEPARTMENTS

ON THE WEB
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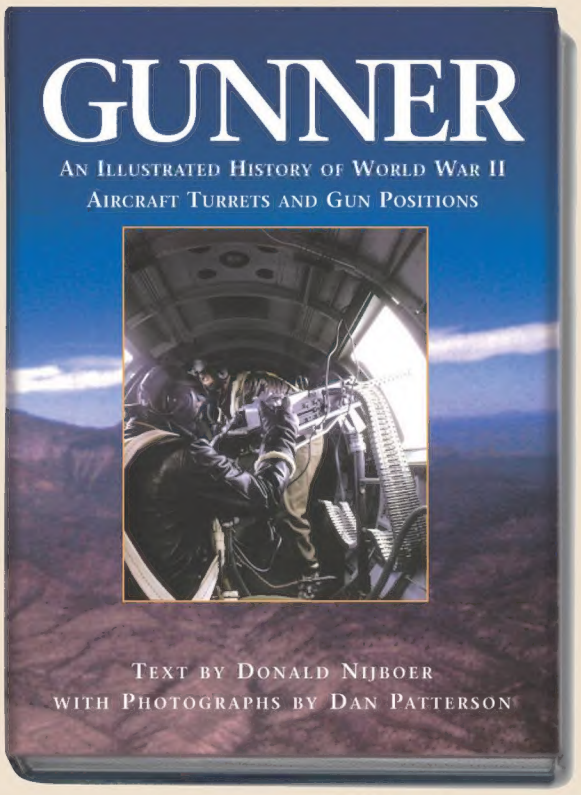
NEW, ORIGINAL, WEB-EXCLUSIVE features make it more fun than ever to visit our Web site (see p. 12), where you'll also find videos and photos related to this issue's articles. AND HELP US PICK the next *Air & Space* cover! Vote for your choice in an online poll.

BOOKS THAT AVIATION HISTORY BUFFS WILL LOVE

Donald Nijboer



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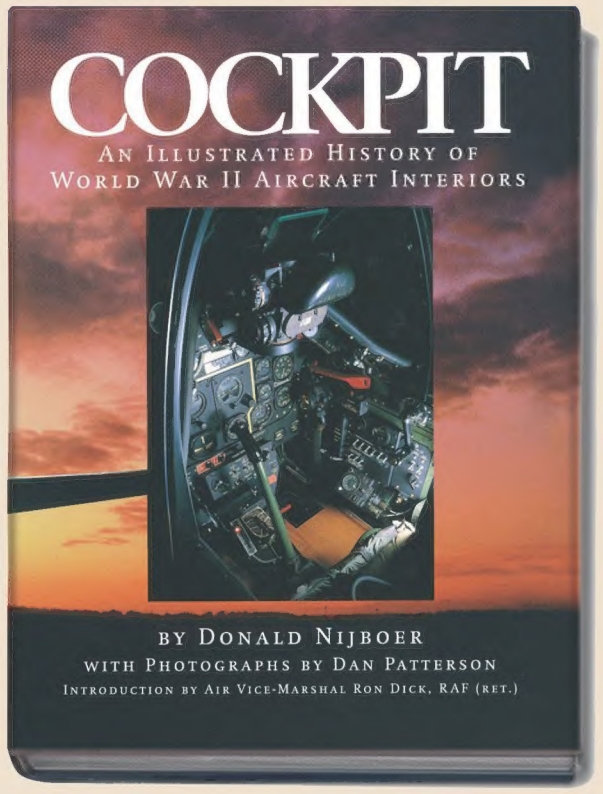

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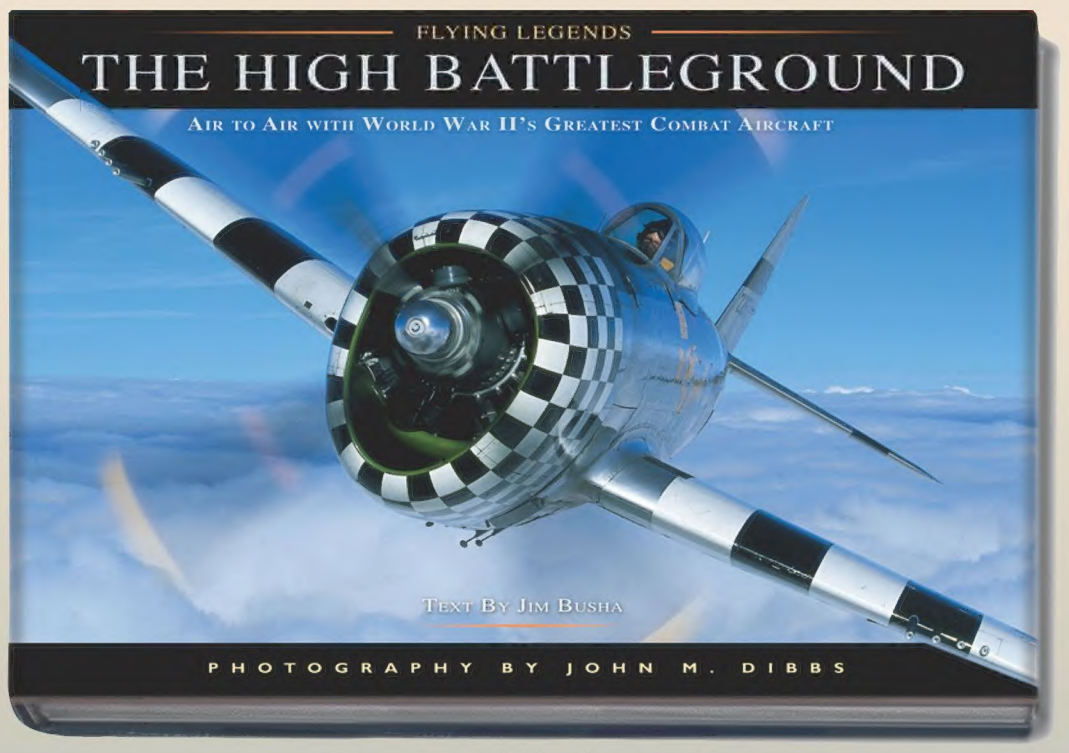

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Virtual Gallery

More than 360 famous aircraft are in the collection of the National Air and Space Museum. Many can be seen at the flagship building on the National Mall, and at the Steven F. Udvar-Hazy Center in Virginia. Others are on loan to other aviation and space museums. As significant as these artifacts are, they represent less than one percent of the Museum's total number of artifacts.

The single largest group of artifacts belongs to a category we call "flight materiel." This category includes more than 17,000 artifacts, among them military and airline uniforms, flight clothing, medals and ribbons, uniform insignia, parachutes, trophies, and personal memorabilia. The artifacts represent all military services and every conflict in which U.S. military aircraft flew. There are also mementos of long-forgotten airlines and of civilian exhibition flying. International in scope, the collection represents 87 countries.

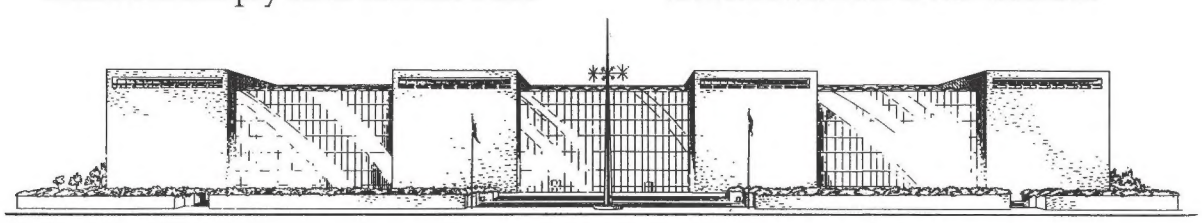
Although it is possible to see thousands of these objects on display at the Museum's two locations, many more remain part of our study collection, kept in storage, out of public view. The study collection includes space artifacts too, such as satellite navigation and control devices and simple computer keyboards from Apollo spacecraft. In some cases, the objects are so fragile that displaying them would compromise their long-term preservation. In other cases, the Museum simply does not have the resources or space to display the artifacts.

To make even undisplayed objects available for public viewing, the National Air and Space Museum's curatorial and collections staff has embarked on an e-Museum project. Staff members are making digital images of objects and writing short descriptions and histories of them to be posted on the Museum's Web site: *http://collections.nasm.si.edu/code/emuseum.asp*. This is a monumental task, since 85 to 90 percent of the 52,000 artifacts in our possession were collected before the advent of the personal computer.

Like our famous aircraft, the smaller artifacts come from donors who form a Who's Who of aviation history, such as Charles Lindbergh, Amelia Earhart, Jimmy Doolittle, Billy Mitchell, Eddie Rickenbacker, Hap Arnold, Curtis LeMay, Scott Crossfield, Juan Trippe, Chuck Yeager, and Patty Wagstaff. They also come from donors who are not famous, but whose contributions are just as important. Their donations help tell the many and varied stories of aerospace history.

Keep looking for new artifacts to appear on the Museum's Web site through e-Museum. And when you visit our two locations, on your way to see your favorite air- or spacecraft, take time to look in the display cases. If you don't, you are sure to miss all sorts of small treasures.

J.R. DAILEY IS THE DIRECTOR OF THE NATIONAL AIR AND SPACE MUSEUM.



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LETTERS

Cat Tales

I'm confused. In your Tomcat Tribute (Aug./Sept. 2006), you ran a photograph of Commander Dale Snodgrass' entry pass in an F-14 ("The Real Top Gun"). This photo has been circulating for some time on the Internet with this caption: "This is an actual fly-by during the deployment of the Nuclear Aircraft Carrier USS *Stennis*. The pilot was grounded for 30 days, but he likes the picture and thinks it was worth it. Yikes!" However, the caption you published says the photograph was taken on the summer 1988 Dependents Day Cruise on the USS *America*. Which account is true?

Robert D. Garrison
Schoolcraft, Michigan

Dale Snodgrass replies: The caption in the magazine is correct. For the record, the entry had preapproval, and neither the pilot nor the RIO [radar intercept officer] got in trouble.

I was particularly interested in the picture of nine F-14s in a diamond formation on page 33. I was in the ninth (right-most) F-14.

There are errors in the caption. I was a RIO in F-14 squadron VF-24 from December 1975 through October 1977; looking at my flight logbook, I've determined that the picture was taken on May 3, 1976, not in 1981. Also, back then, squadron VF-24 was known as the Checkertails, not the Fighting Renegades. And the photograph shows us en route from Naval Air Station Miramar, California, to NAS Fallon, Nevada.

Cmdr. Will O. "Willow" Wood
U.S. Navy Reserve (ret.)
Plano, Texas

You publish a special section saying farewell to the Tomcat, and the best quote you can come up with about RIOs is one from a pilot about a time the RIO didn't punch them out ("Do You Have It?")? C'mon, you could have done better than that at representing this proud group of professionals.

Lieut. Hillary O'Connor, U.S. Navy
Fallon, Nevada

My brother would have enjoyed your tribute. He, Charles A. "Chuck" Sewell, was Grumman's chief test pilot from 1971 (after Bob Smyth) until 1986. While he was there, he flew every aircraft the company manufactured, but he loved the F-14 and flew it as often as he could. He was especially known for the tests of the asymmetrical wing sweep, in which one F-14 wing was maintained at the full forward position while he swept the other through its sweep range (see photo, p. 34, How Things Work: Swing Wings). For these tests and others, he received several prestigious awards, including two Ivan Kincheloe Awards for Test Pilot of the Year from the Society of Experimental Test Pilots.

His last achievement was first flight of the X-29 forward-swept wing aircraft. He died in 1986, flying a TBM Avenger.

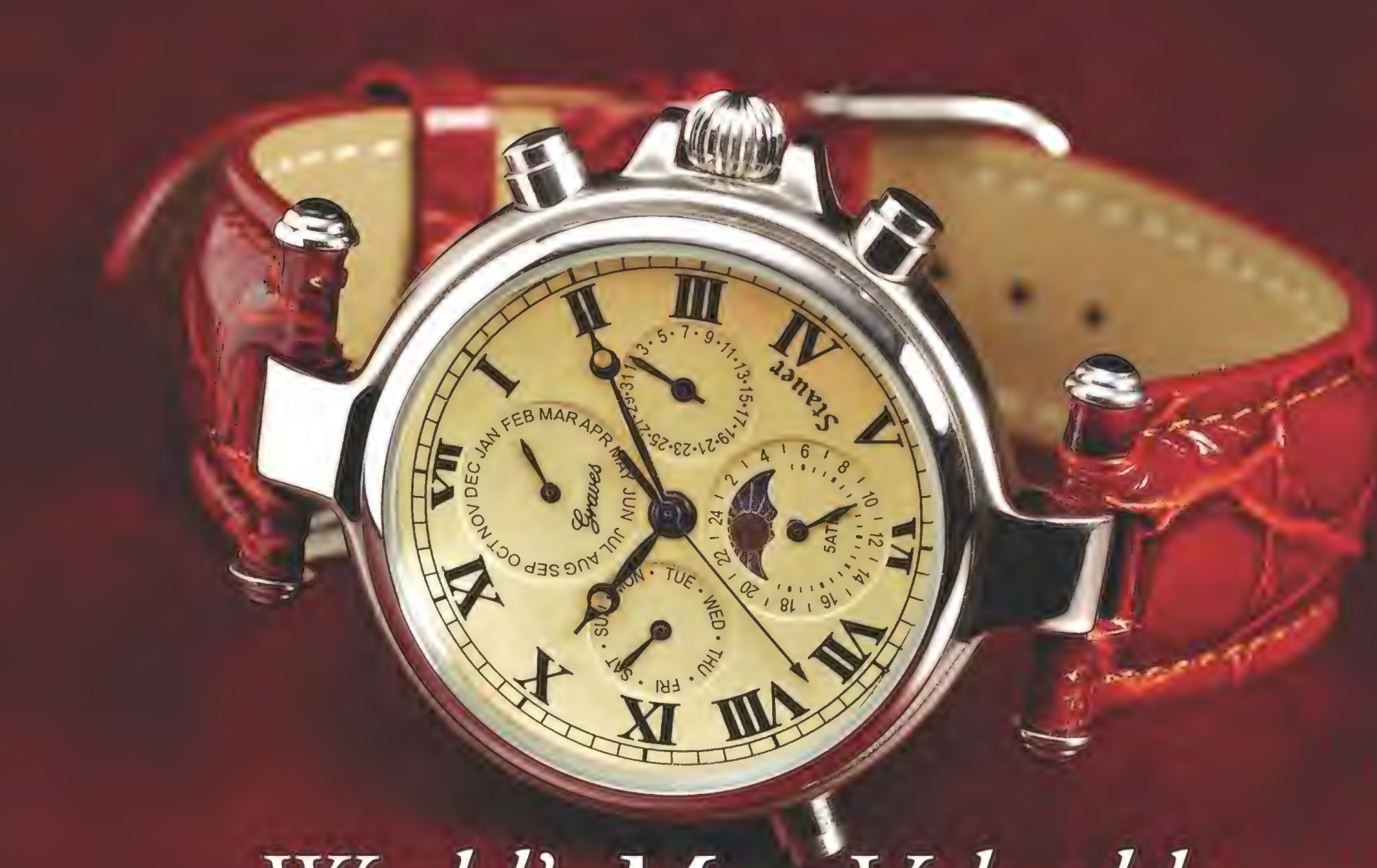
Ken Sewell
Dallas, Texas

While I respect and admire the F-14, and I will readily concede its air-to-air capabilities are far superior to those of its developmental predecessor, the F-111, I must take exception to the statement by Jay Yakeley ("Shock and Awe"). I have flown alongside Tomcats at Red Flag excercises, and when it comes to speed—down low or up high—it's the Aardvark that nothing could keep up with. I routinely took the -111 above Mach 2 at 50,000 feet on Functional Check Flights, and hit 800 knots [920 mph] on the deck at Red Flag.

Eric Schultz
Corona del Mar, California

Rickenbackerology

In his review of W. David Lewis' *Eddie Rickenbacker: An American Hero in the Twentieth Century* (Reviews & Previews, Aug./Sept. 2006), Daniel Ford says that



World's Most Valuable Timepiece Disappears

Back in 1933, the single most important watch ever built was engineered for a quiet millionaire collector named Henry Graves. It took over three years and the most advanced horological technique to create the multifunction masterpiece. This one-of-a-kind watch was to become the most coveted piece in the collection of the Museum of Time near Chicago. Recently this ultra-rare innovation was auctioned off for the record price of $11,030,000 by Sotheby's to a secretive anonymous collector. Now the watch is locked away in a private vault in an unknown location. We believe that a classic like this should be available to true watch afficionados, so Stauer replicated the exact Graves design in the limited edition Graves '33.

The antique enameled face and Bruguet hands are true to the original. But the real beauty of this watch is on the inside. We replicated an extremely complicated automatic movement with 27 jewels and seven hands. There are over 210 individual parts that are assembled entirely by hand and then tested for over 15 days on Swiss calibrators to ensure accuracy. The watches are then reinspected in the United States upon their arrival.

27 jewels and 210 hand-assembled parts drive this classic masterpiece.

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Eastern Airlines made a bad choice of jetliners. What was it?

William Beagan
Manalapan, New Jersey

Ford writes that Rickenbacker joined the U.S. Army as General "Black Jack" Pershing's chauffeur. However, Rickenbacker recounts in his autobiography: "The truth is that I never did drive for the General."

Rev. Winston E. Clark
Leesburg, Florida

Daniel Ford replies: According to Lewis' biography, Rickenbacker spent $100 million on Lockheed L-188 Electra turboprop airliners, spares, and options—a huge sum for the 1950s. Though the Electra eventually turned out to be a success, early models suffered from wing flutter, and at least two crashed at other airlines. The government put speed restrictions on the plane, making Eastern's Electras much slower than competing "pure" jets from Douglas and Convair.

As for Rickenbacker's chauffeuring Pershing, Lewis notes instances in which both men referred to it. But it does seem true that the future ace did most of his driving for lesser officers, including Billy Mitchell.

The Curtiss Solution

"Glenn Curtiss Slept Here" (June/July 2006) failed to include the main reason Glenn Curtiss is considered one of the greats of aviation. The Wright brothers developed the idea of wing warping, which enabled an airplane to make banked, controlled turns. While a major advance, the technique required the pilot to twist his body to move a wooden cradle, which in turn was attached by pulleys to the wingtips. It was uncomfortable and difficult.

Curtiss invented what are known today as ailerons: flap-like devices on the wings that enable the pilot to bank and turn by moving a stick or wheel, rather than by contorting himself.

Robert Potts
Essex, Connecticut

COURTESY JOHN V. SCHIPPERS

Spotted over Iowa: Navigational aid or snide comment?

Painter With an Attitude

"Show Me the Way to Go Home" (Aug./Sept. 2006) prompted me to find the enclosed photo [above]. According to my pilot logbook, I took it in July 1967, when I flew a Cessna 172 from California to my small hometown, Pleasantville, Iowa. The sign certainly helped me find a grass strip three miles northwest of town. As for the town's name, residents debated if the painter had in fact intended this spelling.

John V. Schippers
Mokelumne Hill, California

Remembering George Hall

I was sorry to hear of George Hall's passing (Sightings, Aug./Sept. 2006). In 1973 I was a mechanic on the Goodyear blimp *America*, and that summer George traveled with us while taking photos for what later became *The Blimp Book*.

That Thanksgiving, we had George and others over. When it was time for dessert, my wife Cindy asked the guys what kind of pie they wanted, as she had made three kinds. Everybody selected one except George, who said, "I'll have one of each." We always wondered where he put all the food—he was so tall and thin.

When I worked with George, he always had time for explanations or just conversation. He was a most generous and funny man.

Jim Oliver
Portsmouth, New Hampshire

Corrections

Aug./Sept. 2006 "The Grumman Cats": Jimmy Thach's name was misspelled.

"Persian Cats": The Farsi writing on the patch on p. 38 says "Tomcat," not "Anytime, Baby."

Apr./May 2006 "Airshows 2006": The airshow at Seymour Johnson Air Force Base, Goldsboro, North Carolina, will held be on October 15.

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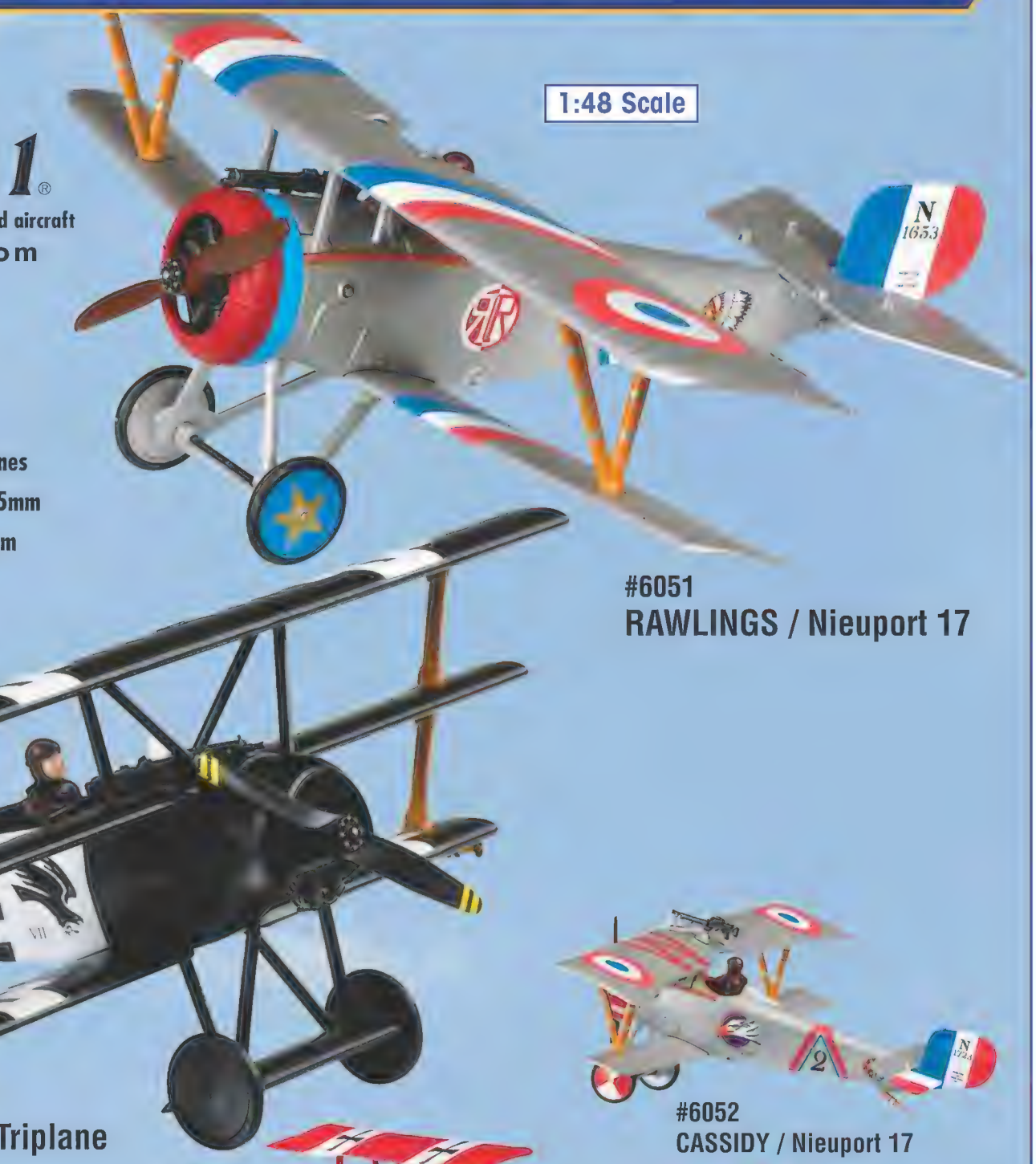

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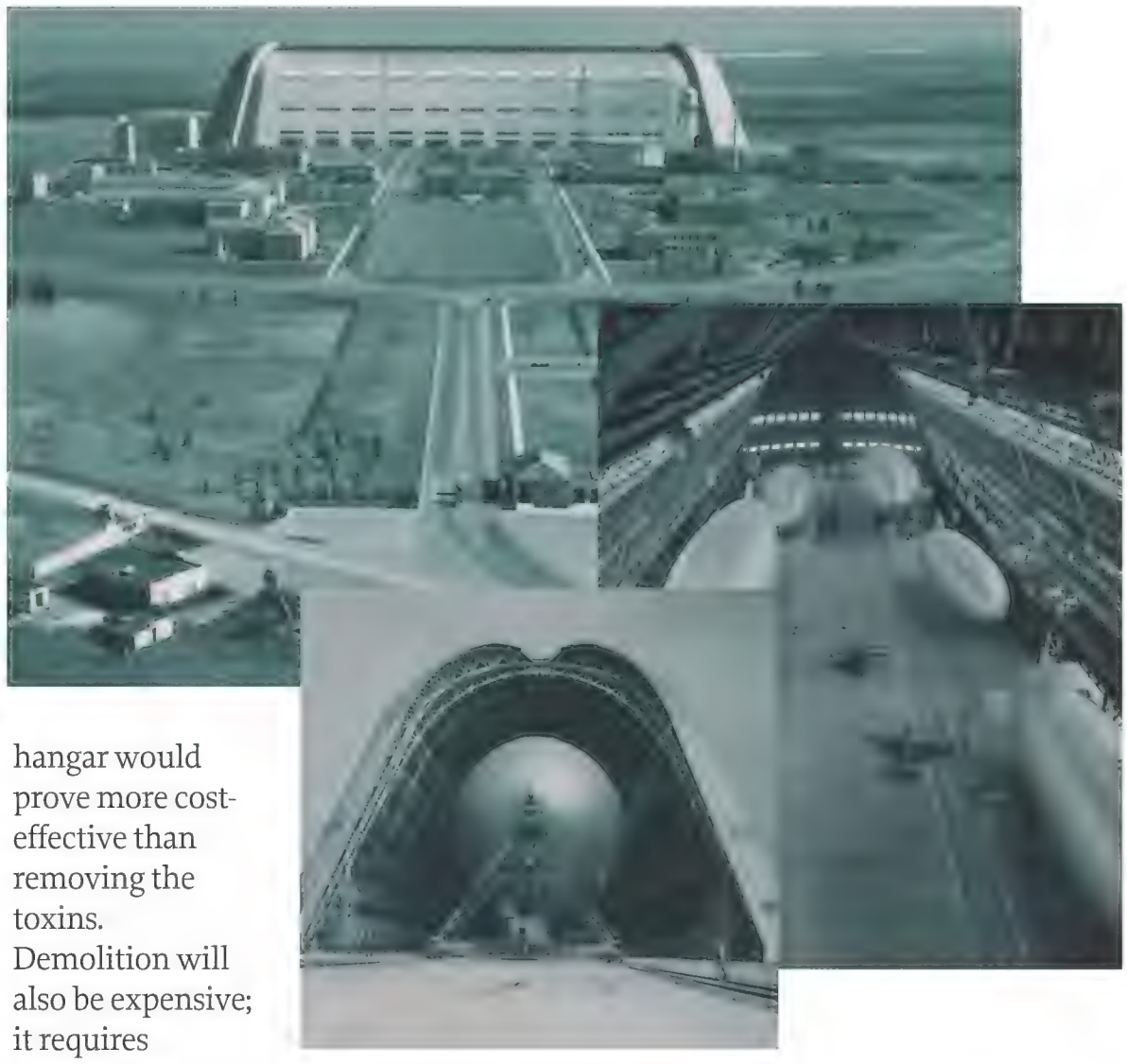
Hangar One Hanging On

BIG ENOUGH TO COVER seven football fields, Hangar One at Moffett Field, 30 miles south of San Francisco, stands as one of the last links to the era of giant airships. That link itself may soon vanish, but not before a fight by activists.

Four years ago, environmental officials discovered that polychlorinated biphenyls—PCBs—from the hangar's metallic skin were leaching into nearby wetlands. The U.S. Navy's Base Realignment and Closure program, charged with identifying the best uses for decommissioned military bases, has calculated that demolishing the hangar would prove more cost-effective than removing the toxins. Demolition will also be expensive; it requires dismantling the eight-acre structure (whose signature "orange peel" doors each weigh 500 tons), built in 1933 on land sold to the Navy for $1 by a community hoping for a new era of air transport.



MOFFETT MUSEUM (3)

Clockwise, from top: Hangar One in 1934, at Sunnyvale Naval Air Station; housing reconnaissance blimps during World War II; disengorging the original occupant, the *Macon*, in 1934.

The hangar's original occupant, the airship USS *Macon*, crashed in 1935, 22 months after sister ship *Akron* went down; the destruction of the *Macon* effectively ended the U.S. airship experiment. Smaller blimps patrolled the West Coast to prevent a Japanese invasion during World War II, but buoyant flight never recovered.

Hundreds of pro-hangar citizens have crowded recent public hearings. "We've heard from the son of a technician who once operated the hangar's giant doors," says Save Hangar One Committee spokesman Steve Williams, "as well as the grandson of a colonel who crashed aboard the *Macon*." Committee founder and environmental advocate Lenny Seigel worries that the Navy is overstating restoration costs to rid itself of a perceived white elephant. "If we lose this engineering marvel," Seigel says, "we can never build its like again." Last July, facing the uproar, the Navy heaved a great sigh and said it would get another estimate on the cost of demolition versus restoration.

If Hangar One wins, one proposed use is making it an aerospace museum, "Spaceworld." Another plan would use the structure as a giant emergency-preparedness stockpile, or even headquarters for a new generation of surveillance blimps, a return to the homeland security detail the hangar assumed during World War II.

NICK D'ALTO

UPDATE

Location, Location, Location

In an effort to raise money to build a new facility, the management at Santa Paula Museum of Aviation in California is constructing 32 condominium/hangar units on the airport, with prices starting at $640,000 (see "The People and Planes of Santa Paula," Feb./Mar. 2004). Each hangar will accommodate a light twin-engine aircraft; condos, up to 1,200 square feet, will have two bedrooms, two baths, and a balcony. Sixty takers are already lined up.

ARCHIVES

A Bigger, Better Griffith

Griffith Observatory, a Southern California icon perched on Mount Hollywood, will re-open in early November after a $93 million overhaul. The observatory, funded by philanthropist and astronomy enthusiast Griffth J. Griffith, opened in 1935 and featured a planetarium and a refracting telescope.The renovation expanded visitor space by 40,000 square feet, upgraded the planetarium with digital laser projection technology, and added 60 exhibits.

Right: Observatory director Dinsmore Alter with the "Welcomettes" and the original Zeiss planetarium projector in 1937; above, today's Zeiss Mark IX Universarium projector in the new Samuel Oschin Planetarium.

OPPOSITE: ANTHONY COOK; LEFT: GRIFFITH OBSERVATORY COLLECTION

Where Did All the Airports Go?

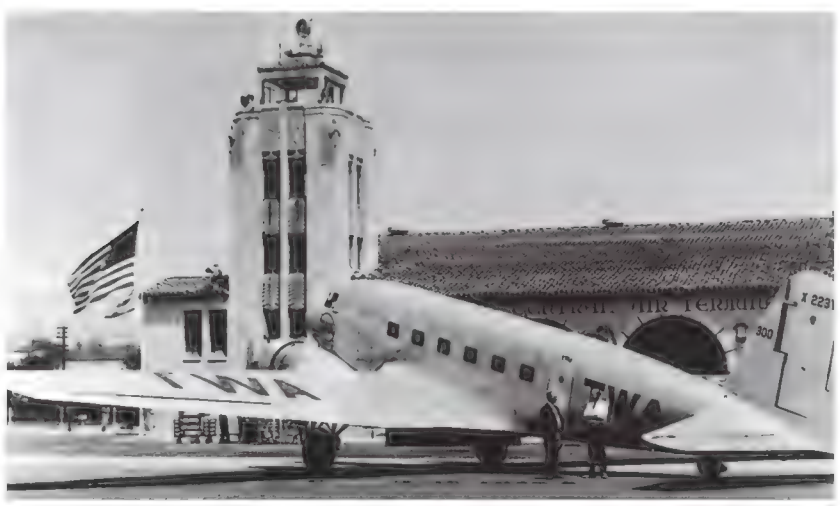
One sunny day in the late 1990s, Paul Freeman was out puttering around in his single-engine airplane when he happened to spot the remains of an old airport. Upon inspection of the sectional chart, he spotted other abandoned airports, printed only as landmarks or for emergency landings. Freeman, an aerospace engineer for Rockwell Collins, began searching for more fields, trying to learn their origin, when they were abandoned, and why. And that's how the Web site *www.airfields-freeman.com* was born.

"The number of write-ups just snowballed as more and more readers of the site sent in information about other former airfields," he says. Now, after seven years, the site includes about 1,400 old fields. Most entries have a couple of paragraphs about the place, a section of a vintage chart that shows the field's location, and a few before-and-after pictures.

The desert southwest is littered with World War II training airfields. "They have amazingly expansive runways with no nearby communities to use them, so they just sat there," he says. "Given the desert climate, they're there forever." A few, like Manzanar Army Airfield, in Manzanar, California, were built as "fallback" fields in case the Japanese invaded the West Coast and U.S. forces needed to pull back. Most of them had no infrastructure. "There are quite a few of those in remote areas," Freeman says. "They sat there for years and years, though some of them were reborn as general aviation airports."

And some are gone without a trace. There's Roosevelt Field, the grass runway in Garden City, Long Island, where Charles Lindbergh's *Spirit of St. Louis* bounced slowly into the air at the start of its historic trip to Paris. In its place is a shopping mall, called, fittingly, Roosevelt Field Mall. And there's Greater Southwest International/Amon Carter Field, built two miles south of today's Dallas/Fort Worth International. "It only operated about 16 years before the U.S. government got Fort Worth and Dallas to join together to build DFW," says Freeman. Construction crews ripped up the pavement and removed all traces of the field, except a few buildings and the trees that lined the entrance to the terminal. And many airports were just local fields that were gradually surrounded by suburbia and succumbed to noise complaints. "A number of airports were lost that way throughout the years," Freeman laments. "I wish they were still there."

PHIL SCOTT



NASM (SI NEG. #80-10743)

Dedicated in 1929, the Grand Central Building housed the control tower and terminal at Grand Central Airport in Glendale, California. The airport was closed in 1955, but the building, now a National Historic Landmark and owned by Disney, still stands.

Mirror, Mirror, on the Moon

Hubble's successor, the James Webb Space Telescope, is expected to peer even further back in time when it is launched in 2013, but even with a 21-foot-diameter primary mirror—seven times larger than Hubble's—the new observatory won't be able to pick out individual stars and other features of the early universe. That got a bunch of astronomers thinking about how to put up a really large telescope without being laughed out of NASA's beleaguered budget office.

They came up with the notion to do away with a solid mirror altogether. In a paper presented at the International Society of Optical Engineering

ON THE WEB SITE

New Look at *www.airspacemag.com*

We have redesigned our Web site to feature Web-only interviews, profiles, essays, airshow reports, behind-the-scenes looks at National Air and Space Museum artifacts, and discussions among experts in aviation and spaceflight.

New departments on the site:

Snapshot, brief reflections on happenings and curiosities, drawn from historic archives and the current headlines.

Need to Know, a chance for readers to get answers to their most perplexing aviation or space questions (e-mail *pappalardoj@si.edu* to pose a question).

My Favorite Artifact, in which museum curators talk about the air and space objects they love best.

The site will continue to supplement and enhance the magazine's content. Look for a video clip of the hovering and vertical-landing X-plane that preceded the Joint Strike Fighter ("Weight Watchers," p. 66), World War II military records and photographs that revealed the identity of an unknown airman (Above & Beyond, p. 16), and more photos chronicling the reconstruction of one of the world's first combat jets ("Stormbird," p. 20).

See more Me 262 photos at the expanded *www.airspacemag.com*.

JIM LARSEN

conference in Orlando, Florida, last spring, researchers proposed a telescope with a 12- to 62-mile-diameter mirror of spinning liquid.

The theory dates to Isaac Newton, the inventor of the reflecting telescope, but the technology to create a viable liquid-mirror observatory was developed only in the past 10 to 20 years. The idea is to steadily spin a liquid, such as mercury, inside a bowl-shaped container. Thanks to the laws of physics, its surface becomes a parabola, which happens to be the perfect shape for a telescope's mirror. The drawback is that the mirror must stay fixed in one position—straight up—limiting the scope of astronomical investigations. For some studies, though, such as Hubble's famed deep-field view, straight up is exactly what astronomers want.

Liquid-mirror telescopes have one huge advantage: Construction costs are minimal compared to those of traditional observatories. The University of British Columbia, for example, built a 20-foot liquid-mirror telescope in Vancouver, Canada, for about $1 million, a mere fraction of the cost of a rigid-mirror observatory of similar size.

On Earth, liquid mirrors cannot get much bigger than 23 feet in diameter before their surfaces are distorted by the wind the telescopes generate by spinning. That wouldn't be the case on the moon, says University of Arizona astronomy professor Roger Angel. With no atmosphere to contend with and greatly reduced gravity, the moon would be an ideal spot for a large liquid-mirror telescope, he says.

Researchers are still investigating suitable liquids for creating a mirror on the frigid moon. Mercury, the preferred substance for Earth-based liquid-mirror telescopes, would freeze. The answer may be to evaporate a reflective coating, such as silver or gold, onto a cryogenic liquid.

Lofting the materials to build a telescope on the moon, not to mention the challenging construction project, would be an expensive undertaking. But with NASA's future hinged on exploration beyond Earth orbit, a lunar telescope would give the agency some much-needed staying power, says Angel. "If the public is going to support going back to the moon, clearly you have to do something qualitatively more than what you did on Apollo."

IRENE KLOTZ

"The Girl in Aviation"

The Raab Collection in Ardmore, Pennsylvania, which deals in historic papers, recently unveiled a trove of letters and by-laws that served to establish the Ninety-Nines. The women pilots' organization, named for the number of attendees at the first meeting, today claims 5,500 members in 35 countries. The collection came to the market through Raab when its owner, Eleanor Spear, died last January at age 95.

Spear's 1929 letter of invitation to all 117 licensed U.S. women pilots in the United States notes that "[i]t need not be a tremendously official sort of organization.... We would not need a lot of officers and red tape." In another letter, Opal Kunz argues why such a group was needed: "We are trying to bring about a different attitude toward the girl in aviation, whereby she is accepted as an equal rather than spoiled as something rare and very precious. So far the girl fliers have received much more gratitude than we deserve in proportion to our achievements.... Women have a future in aviation only so long as we prove to be of value. This does not mean publicity value."

The Raab Collection priced the set of documents at $16,000; last August, the Library of Congress snapped it up. "I happened to see the Raab catalog just as my chief said something he rarely ever does: 'We have a little money to spend right away. Any good candidates?' " says Leonard Bruno, curator of science and aviation manuscripts. "It didn't take much to see that this was a one-of-a-kind collection, which is what we always seek, so it was an easy sell."

PATRICIA TRENNER

"Did We Forget Something on the Checklist?..."

Last June, a Royal Australian Air Force F-111C (see "Big Pig," Feb./Mar. 2002) shed its left main-gear wheel during takeoff from Queensland's Amberley Air Force Base. So informed by air traffic controllers in the tower, Flying Officer Peter Komar—fresh out of F-111 training—and Flight Lieutenant Luke Warner spent the next three hours hashing over the situation with crews on the ground and circling over southeast Queensland, burning off fuel to lighten weight and enable a slower final approach speed.

Group Captain Leo Davies said that based on a successful gear-up landing executed by a U.S. Air Force F-111 a few years back, the decision was made to do the same with the Australian aircraft. "The crew configured themselves in a normal approach configuration—except for the landing gear, of course," he told a local ABC radio reporter. "They touched down short of the arresting cable, allowed the hook to engage the cable, and it ran out and stopped them. Textbook emergency landing."

AUSTRALIAN GOVERNMENT DEPARTMENT OF DEFENCE (2)

"...We must have, because it's taking full power to taxi to the ramp."

Many U.S. Air Force fighters have a tailhook that can snag an arresting cable on a military runway in case of a brake failure or other problem that might cause an overshoot. But unlike the beefier naval aircraft tailhook, an Air Force tailhook is for one-time use only.

PATRICIA TRENNER

AIR & SPACE INTERVIEW

Simon "Pete" Worden

DIRECTOR, NASA AMES RESEARCH CENTER, CALIFORNIA

Named as Ames' director in April, Worden retired from the Air Force in 2004 after 29 years, including a stint as director of development and transformation at Space Command, Los Angeles Air Force Base. Worden, who has a doctorate in astronomy, has also been an astronomy researcher at the University of Arizona and has authored or co-authored more than 150 scientific papers on civil and military space.

What's the most significant contribution Ames is making now to returning astronauts to the moon?
We're the lead for the thermal protection system. That's pretty critical. You don't get back home without it. In addition, we're going to be assuming a lead role in the information technology area. That's still being defined, but the collaborative design and development tools and the computer support efforts are really critical. We're also playing a key role in the robotic program.

What's the most important thing any country has accomplished in space since the launch of Sputnik, 50 years ago?
I think probably it is looking back on the Earth and getting the perspective that we're all living on this one little piece of rock and we're part of a great big universe. It's both a frightening and promising look, the perspective that space offers an incredible future. Seeing the Earth from space is pretty significant.

Where will we be in space exploration 25 years from now?
I certainly hope we're on the moon and Mars, and I might add that near-Earth asteroids are a very exciting additional set of targets. I would think that in 25 years the most important thing we would have is people that are permanently living off the planet. Living and thriving and settling.

When did you get your pilot's license?
When I was 17. My dad was a corporate pilot and an Air Guard pilot, and we had a little light airplane that he trained me in. Most people say they're really scared when they fly solo. Well, my dad used World War II training techniques, which meant the moment I got in the airplane his mouth opened and it didn't close until the engine cut off. You know, non-stop yelling and colorful language. I was so glad when he was out of the airplane. In fact, I even did one or two things wrong [during my solo flight], and he was on the ground shaking his fist at me.

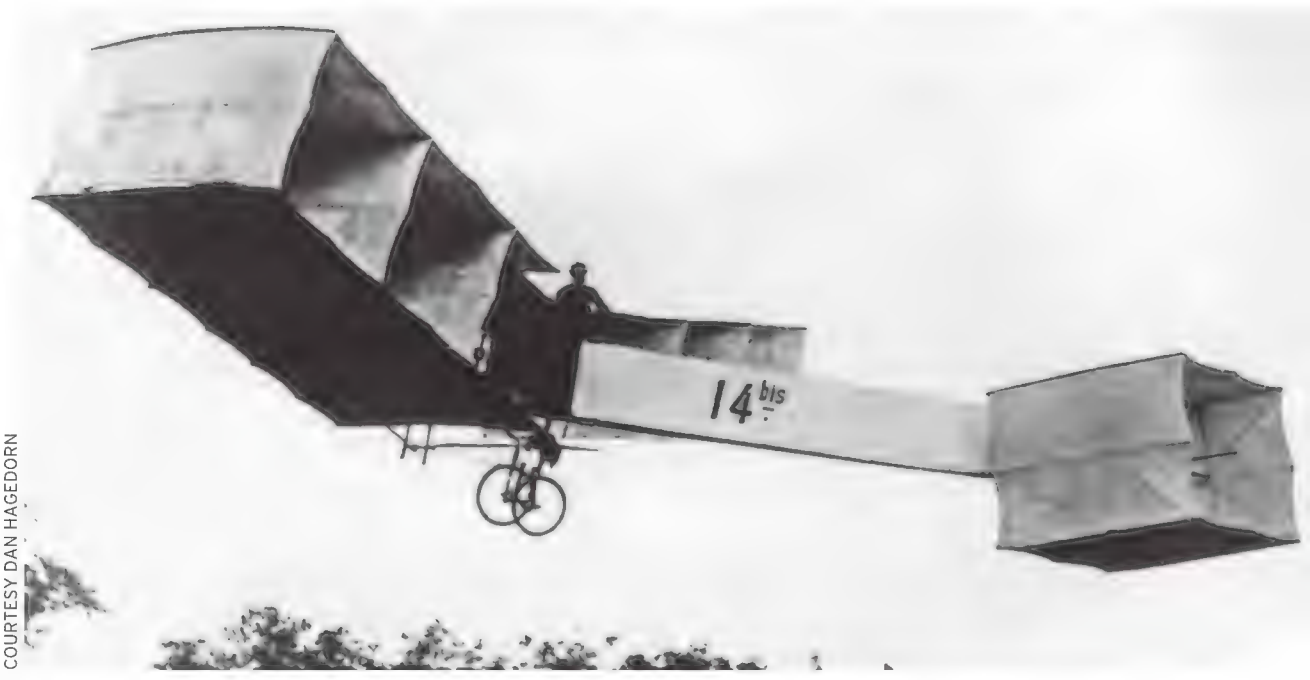
NASA AMES RESEARCH CENTER

Worden went for a spin in a PT-17 Stearman Kaydet that dropped in at Moffett Airfield in California during a Collings Foundation tour this year.

The first space age saw a breakthrough in computer technology. What breakthroughs do you foresee for the next era in space exploration?
I think it's probably the ability to live off the land. In some sense, a human settlement is a self-replicating entity. And I think that the technology to do that is a combination of manufacturing, biological, energy, and other things. It's sort of a synthesis of dozens of different technologies that enable you to not only live but to expand. You might call it the development of an Earth seed, a planet on another planet that can survive by itself and produce more. The first space age was getting there. The next space age is living there.

The Spirit of Santos-Dumont

On October 21, the National Air and Space Museum will celebrate the 100th anniversary of a first flight. Alberto Santos-Dumont, a Brazilian who spent his adult life in France, was the pilot of this particular milestone (which occurred October 23, 1906). He rolled his *14 Bis*, which resembles a jumble of oversize box kites, out to a field at the Bagatelle, just outside Paris, France, and lifted gently into the sky...well, "sky" such as it is nine feet off the ground. In the end, he flew 120 feet before touching down and rolling to a stop. It was the first flight of a heavier-than-air craft in Europe.



COURTESY DAN HAGEDORN

Alberto Santos-Dumont's *14 Bis* had three distinctly different sets of controls, which provided the aircraft's stability.

The Museum will hold a Family Day this October—a themed event occurring several times a year, geared toward school-age children and their parents—to celebrate the centennial. The Brazilian Embassy will join the Museum in fêting Santos-Dumont's flight, as well as honoring his contributions to the evolution of aviation. A replica of Santos-Dumont's final design—a delicate, bird-like *Demoiselle* (Dragonfly), provided by Brazil's Instituto Arruda—will be on display. "It's really the first practical ultralight," says Dan Hagedorn, archivist and adjunct curator of Latin American aviation at the Museum. The *14 Bis* will be there in spirit—as a 1/16th-scale model—as will Santos-Dumont's *No. 9* dirigible. And 40 Santos-Dumont postage stamps from around the world will be enlarged and on view.

COURTESY EMBRAER (CENDOC-BRAZIL)

Kids can construct paper models of the aircraft they see and take home an assortment of posters and pamphlets as well. In addition, Elisabeth P. Waugaman will read from her illustrated children's book, *Follow Your Dreams: The Story of Alberto Santos-Dumont*. And there's even something for music fans. "We discovered some special sheet music dedicated to Santos-Dumont," says Hagedorn. The challenge for event organizers will be finding people who can play the old instruments the music requires.

Although there will be several replicas and models on display, unfortunately, original parts of any of Santo-Dumont's aircraft are very difficult to find. "No one knows what happened to the *14 Bis*," says Hagedorn. "You can see components of the *14 Bis* hanging on the wall [in a photograph of Santo-Dumont's workshop in Bagatelle], where he was building the *No. 19* and *No. 20*, which

NASM (SI NEG. #A-30556)

A taciturn Santos-Dumont (above); *No. 9*'s engine, which generated all of 3 horsepower.

leads me to believe he cannibalized his older aircraft to build new ones." However, the Museum does have an original engine from Santos-Dumont's *No. 9* on display in the Early Flight gallery, in an alcove next to a French Blériot XI monoplane.

"Santos-Dumont's flight really was a first," says Hagedorn. "The Wrights did trials in a glider replica...to learn how to control it [prior to their first trip in the *Flyer*]. Santos-Dumont literally taught himself to fly that very day he lifted off."

It was reported that Santos-Dumont looked like he was doing the rumba when he was flying. Some of the controls for the *14 Bis* were attached to his shoulders by a harness, so he was constantly shimmying and shaking as he flew. Santos-Dumont was fairly small, which was probably to his advantage in the lightweight aircraft, says Hagedorn. The *14 Bis* was his 14th design, powered by a 50-horsepower Antoinette engine.

The *Demoiselle* was, for all intents and purposes, Santos-Dumont's first "practical" aircraft design. "The *Demoiselle* is Santos-Dumont's legacy," says Hagedorn. "So many were built that there's no record of the precise amount that existed." The silk-wing monoplane was a far cry from the *14 Bis*' enormous stretch of boxy canvas. Powered by a 20-horsepower Dutheil and Chalmers engine, the entire aircraft, including diminutive pilot Santos-Dumont, weighed just 233 pounds.

Santos-Dumont made his last flight in July 1910. He was diagnosed with multiple sclerosis some years later, and died by his own hand, despondent and alone, on July 23, 1932.

"Santos-Dumont made a gift of his aircraft designs to the world," says Hagedorn. The inventor eventually burned almost all of his papers and manuals in his later life, however, leaving very few artifacts (aside from photographs) of his accomplishments. This October will give the public a chance to celebrate this reluctant hero and his exciting flight 100 years ago.

BETTINA H. CHAVANNE

ARTIFACTS

DANE PENLAND

Utili-copter

The Sikorsky YH-19A (a.k.a. the S-55) is billed as the world's first single-rotor utility helicopter. The S-55 was flown by the U.S. military throughout the Korean War and went on to pioneer helicopter airline service all over the world. Donor Fred Clark, of Orlando, Florida, has flown this S-55 since 1966, on missions ranging from skywriting to cropdusting to advertising free beer on the Las Vegas Strip. The helicopter now resides at the Udvar-Hazy Center in Virginia.

VISITOR INFORMATION

October 21 & November 11
Saturday Star Party. Join National Air and Space Museum staff astronomer Sean O'Brien in observing celestial objects in dark skies unpolluted by city lights. Sky Meadows State Park, Virginia, 6:15 p.m. to 11 p.m. on October 21; starting at 5 p.m. on November 11. Parking fee: $4 per car. Park phone number: (540) 592-3556.

What's Up
Receive regular updates on Museum events, read about artifacts, get detailed (and behind-the-scenes) exhibition information, and receive calendar listings by subscribing to the National Air and Space Museum's free monthly e-newsletter, *What's Up*. Sign up at *www.nasm.si.edu*.

New (and Discontinued) Bus Service
The Virginia Regional Transportation Association is now offering convenient shuttle bus service between Washington Dulles International Airport and the Steven F. Udvar-Hazy Center. For detailed bus routes and schedules, visit *www.vatransit.org*, and click on "Bus Routes," then "Air and Space Museum shuttle."

Shuttle service running between the Museum and the Udvar-Hazy Center has been discontinued.

Docent Tours
Learn about the Museums' collections and trace the history of air and space travel on free, docent-led tours. At the Museum on the Mall, tours meet at the Welcome Center. At the Udvar-Hazy Center, tours meet at the Docent Tours desk in the Boeing Aviation Hangar. Tours run daily at 10:30 a.m. and 1 p.m.

Location
The National Air and Space Museum is located on the National Mall, along Independence Avenue SW, between 4th and 7th Streets, Washington, D.C. The Steven F. Udvar-Hazy Center is at 14390 Air and Space Museum Parkway, Chantilly, Virginia, near Washington Dulles International Airport.

A Bougainville Mystery

ON DECEMBER 4, 2004, while wandering through a flea market at the Tulsa, Oklahoma Fairgrounds, I came across a picture frame that held three items:

- an American Red Cross envelope on which was written "Air map of a P.38—which was shot down by Zero in Dod [Dog] fight. The piolet [pilot] was killed and plane burned. February 1943";
- inside that envelope, a singed piece of a map showing the southeast tip of Papua, New Guinea;
- a "Surrender Pass," written in both Japanese and English.

I bought the framed group. Curious as to what the items had in common, I started by investigating the map. I contacted Joe Milazzo, a map librarian at Southern Methodist University in Texas, and he responded via e-mail: "[Your map] resembles in its construction some aerial photographic surveys...produced by Tobin." During World War II, that company had turned out maps for the invasion of North Africa and Normandy, among other purposes. I contacted Tobin, but unfortunately, at the end of war, the Army had removed all war-related material from the company premises.

I moved on to the surrender pass. Herb Friedman, who has extensively studied war propaganda leaflets (*psywarrior.com*), looked over the pass and observed: "There is no code so we can't tell when or where it was used."

I turned to the shootdown recounted on the envelope. Though spare, the account included many details: The aircraft was a Lockheed P-38 Lightning; it was lost in February 1943; it was shot down by a Japanese Zero; and the pilot was killed. The map fragment, from the bottom edge, suggested he had been flying over New Guinea or, north of New Guinea, over the Solomon Islands.

Three scraps from World War II: Whose story were they telling?

Assuming the P-38 had been part of the U.S. Army Air Forces fleet, I found a Web site summarizing the U.S. Army Air Forces' Missing Air Crew Reports (*armyairforces.com/dbmacr.asp*). In February 1943, there had been five P-38 crashes in which the pilot was killed. After sending a request to the National Archives, I received microfiche of the MACRs from the five crashes. Three of the reports referred to possible mid-air collisions, and one recounted engine trouble. Those four did not match the information on the envelope. But the fifth MACR, No. 586, was promising (see *www.airspacemag.com*). It told the story of a P-38 piloted by Second Lieutenant Robert P. Rist. His airplane was lost on February 13, 1943, near Bougainville—located in the Solomon Islands. The MACR states: "Last seen by Major Westbrook, 44th Ftr. Gp., with right engine smoking and Zeros on his tail." The Zeros fit my information.

I found more details about Rist's last few days in two books: *Guadalcanal and the Origins of the Thirteenth Air Force* (Army Air Force Historical Studies #35) and *Bill: A Pilot's Story* by Brooklyn Harris (Graphic Press, 1995). On February 13, Rist was flying one of four

RIST: COURTESY BERNICE SALO; OTHERS COURTESY PAUL ROALES

P-38s (along with seven P-40s) that were escorting six B-24s on the second wave of a bombing mission to the Shortland-Buin area. Two P-38s and three P-40s had to return to Guadalcanal, leaving limited fighter cover for the bombers.

The bombers were attacked by 30 Mitsubishi Zeros and 15 Japanese float-equipped fighters, with support from heavy flak fired by naval vessels below.

The U.S. cover fighters dove into the fight. A B-24, its wing and engine on fire, dropped out of formation, and Rist escorted it toward Choiseul Island. Ten to 12 Zeros tried to finish it off. Rist shot down two Zeros, then, out of ammunition, continued to divert the Zeros by diving on them. Finally he was shot down. His efforts enabled Lieutenant Harold G. McNeese to fly his crippled B-24 to the north coast of Choiseul and ditch, which saved the lives of five crew members.

Later, I would learn that on September 10, 1943, fellow 339th Fighter Squadron pilot Darrell Cramer wrote Rist's mother a letter that read in part: "We were greatly outnumbered and Bob dove into the whole enemy force and broke them up long enough for our force to run to safety. I saw the whole thing and it was the most courageous action I have ever seen.... I never saw Bob's plane again but I heard him on the radio so I know he survived the original dive on the enemy but his plane was damaged.... "

Neither Rist nor his aircraft was ever recovered.

According to the Web site of the American Battle Monuments Commission (*abmc.gov*), Rist was awarded the Distinguished Service Cross, the Purple Heart, and the Distinguished Flying Cross. The citation for the latter commends Rist's "aggressiveness, courage and devotion to duty."

I set out to find a member of Robert Rist's family and share information. Rist's enlistment records, in the National Archives (*aad.archives.gov/aad/*), show that at the time of enlistment he lived in North Dakota. The 1930 U.S. Census records list Robert P. Rist as the son of J. Arthur and M. Ann Rist. Robert had one brother and three sisters. The family lived in a coal mining camp in Park County.

Next I consulted the Social Security death records and found someone whose name and age matched the Census data: James Rist—born October 1893, died October 1972—could be Robert's father. If so, that left the mother and siblings as possible survivors. M. Ann Rist had been born about 110 years earlier, so she was probably deceased. According to the Social Security records, Robert's brother had died in 1954. And as for the sisters, if they had married, I did not know their married names.

On the Web, I connected with a genealogy group in the region where Robert's father died: Hennepin County, Minnesota. Charlie Peasha located an obituary for James A. Rist. It gave the married names of Robert's sisters.

I posted a query on the genealogy site, and the next day, a woman e-mailed me the address of an Ellajane Rist Knott, Robert's youngest sister. I sent her a letter and she e-mailed me four days later.

"You surely know how to knock the wind out of my sails!" she wrote. "It was so wonderful to hear my brother's name again. The piece you sent me describing Bob's final moments in the air over Bougainville was moving, he died as he was just beginning life. It is wonderful to know how much he accomplished in his last hours."

The very next day I was contacted by Bernice Salo, the wife of Robert's nephew, who independently was searching for information on Robert and had come across one of my posts on the Internet. She e-mailed: "My husband remembers Bob as a very nice uncle, but he was only five years old when he died. When we go to air shows my husband is always very interested in the P-38's because of his uncle Bob."

Ellajane and Bernice shared materials with me, including newspaper clippings and photographs. I was finally able to fill in some gaps.

Robert was born in Minneapolis, Minnesota, on July 29, 1920. In 1926, his family moved to North Dakota. After graduating from high school there in 1938, he attended the University of North Dakota as a pre-med student, then transferred to the University of Minnesota. On January 20, 1942, he quit college and enlisted in the Army Air Forces as an aviation cadet.

According to North Dakota's *Velva Journal* and other sources, Robert got primary flight training in a Ryan PT-22 Recruit, basic flight training in a Vultee BT-13 Valiant, and advanced flight training in a North American AT-6 Texan. After graduating at Arizona's Luke Field he was shipped off to March Field in California for training in the P-38. In November, he was sent overseas, and later assigned to the 339th. That squadron sent detachments of fighters to Guadalcanal to escort bombers in attacks on Japanese bases on New Georgia, Bougainville, and the Russell Islands.

Three Missing Air Crew Reports referred to possible mid-air collisions, and one recounted engine problems. But the fifth report fit the details on the envelope.

Robert flew his first mission from Guadalcanal on January 13, 1943. On February 10, he scored his first kill: a Mitsubishi Ki-21-I "Sally" heavy bomber. Three days later, he was shot down.

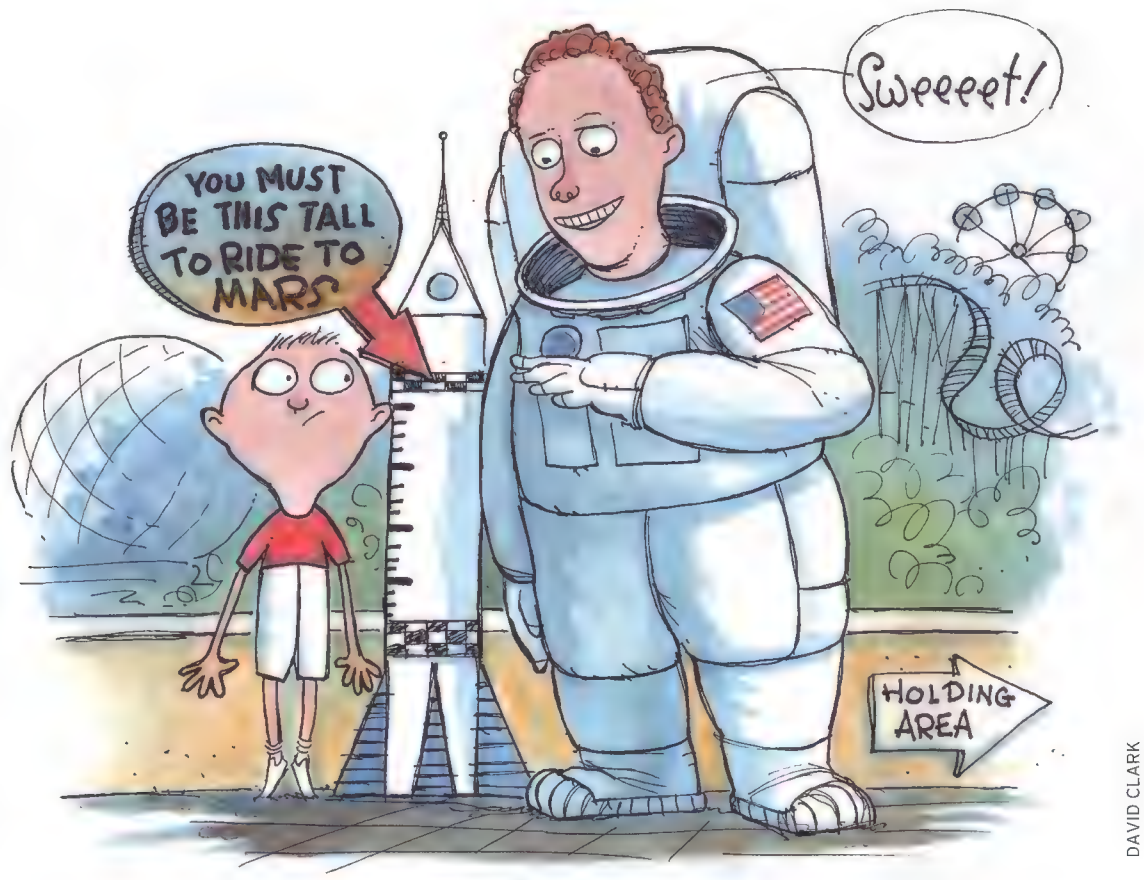
Because his body was not recovered, he was declared missing in action. On December 15, 1945, the War Department listed him as "expired." Robert's family held a memorial service two and a half months later.

Today, Robert is survived by two of his three sisters: Elizabeth Rist Owren of New Jersey and Ellajane in Minnesota. In her e-mails to me, Ellajane helped bring Robert to life in a way that written archives could not. "So many years ago and his memory is still as indelible," she wrote. "He was such a sweet, compassionate man."

The one mystery I never solved concerned the framed assembly of items I'd found at the flea market: Who had preserved them, eventually providing me with a link to the life and death of Robert P. Rist?

PAUL A. ROALES

Cheap Thrills



DAVID CLARK

On July 19, 1969, the day before the first lunar landing, Disneyland's relatively tame "Flight to the Moon" attraction was enough to thrill this 14-year-old. I could easily imagine myself on a future voyage that would match the excitement of Apollo 11.

I never made it to the moon, but I did fly as a shuttle astronaut. Now I wanted to see how well simulation engineering can mimic real spaceflight.

At Disney's "Mission: SPACE" at the Epcot Center in Orlando, Florida, the holding area is dominated by a circular crew compartment, revolving slowly to provide artificial gravity for Mars-bound astronauts. A schematic on a wall introduces the X-2 Deep Space Shuttle, built from carbon nanotubes and powered by solid hydrogen.

Launch technicians funneled 40 of us trainees into an anteroom lined with spacesuits and spacewalking tools, where actor Gary Sinise, astronaut Ken Mattingly in the 1995 film *Apollo 13*, appeared on screen as capcom. Welcoming us to the International Space Training Center, he sketched out our scenario: Each four-person crew would pilot an X-2 on the outbound leg of a journey to the north pole of the Red Planet.

Sinise assigned each of us to commander, pilot, navigator, or engineer, each with specific mission tasks to execute. The bay doors swung open, giving us our first glimpse of the X-2 simulator. Ours was one of 10 crew modules suspended from the overhead arms of a massive, octopus-like centrifuge, carrying 40 passengers. Filing into place with my three crewmates, I pulled down the shoulder restraints and surveyed the familiar shuttle-style switches, push buttons, and labels on the instrument panel.

Cleared to the launch position, the trainer lurched backward, tilting us until we stared at blue sky on our main viewer—*pretty close to the shuttle motion-based simulator back in Houston.* The rumble of ignition rattled our seats and assaulted our ears; rocket exhaust billowed skyward on the external camera view. *Bang!* went the hold-down bolts—liftoff! Two-and-a-half Gs plastered me back into my seat. *Man! Like shuttle first stage on the solids.* On screen, we burst through a thin cloud deck, with a realistic sensation of speed. As the sky darkened, we hurtled past the space station I'd helped build. *We are hauling!* Main engine cutoff pitched us forward in our seats with the onset of virtual free fall. Even slight head motions caused dizziness—capcom had warned us about that. The silence, gentle pitch forward, and star-filled window produced a convincing illusion.

Mission control commanded us to ignite our interplanetary stage for a lunar gravity assist, and we felt an eye-popping burst of power as we screamed past the moon in a 2.5-G pull.

Disney sidesteps months of interplanetary cruise with a few seconds of "hyper-sleep." We woke to a blaring alarm, a looming Mars, and the jarring impacts of asteroids. Mission control initiated an emergency retro-fire, and the Gs came on again as we plunged into the thin Martian atmosphere. Our X-2, hypersonic gliding wings extended, now demanded our collective flying skills, and Capcom Sinise had us grab our hand controllers for final approach. They had no influence whatsoever on our course, but grabbing a stick helped us at least *feel* in control as we threaded through Martian canyons and popped out high and fast over the polar outpost runway. The final dive to the strip mimicked the rumble and pitch of a real shuttle approach, and one more chin-sagging burst of deceleration preceded our barely survivable touchdown on the Red Planet.

After four X-2 missions, I was getting the hang of this Mars thing, but on my fifth liftoff, our commander went off the deep end. We had barely cleared the launch tower when George, a rookie, announced loudly, "I can't do this." Hands over eyes, George answered Capcom Sinise's every call with a panicky "Stop this thing—now!" I was sympathetic, but it was out of my hands—*Sorry buddy, you're going to Mars.* "Just relax, George, take a deep breath," his wife murmured soothingly. "It'll be over soon."

TOM JONES

U.S. Government to Abolish the Lincoln Penny... FOREVER?

Bags of Old "Wheat Back" Cents Released to the Public

WASHINGTON, D.C. — For nearly 100 years, the Lincoln Cent has been a familiar everyday coin. But that may become history if recent legislation such as *The Legal Tender Modernization Act (HR2528)* is enacted, eliminating the one-cent coin forever.

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BOB HAMMER RECALLS THE DAY ten 18-wheel tractor trailers dumped the pieces of five Messerschmitt Me 262 Stormbird jet fighter reproductions in a hangar near the city of Everett, Washington. The pieces had been trucked in from Texas, where an initial attempt to build the aircraft had ended in lawsuits. "Parts everywhere—parts, parts, parts," says Hammer, a retired Boeing engineer. "You never saw such a mess."

That was in December 1998. For Hammer and a small team of volunteers, it was just the start of a long process to put the Me 262 back in the air. Now, the Me 262 Project, as it is called, has logged numerous successful flights and delivered two of the German aircraft, with a third nearing completion. With their project, Hammer and his team have brought the world's first production jet fighter back to life.

>>> by Douglas Gantenbein

The Me 262s could have wreaked havoc on U.S., British, and Russian forces in World War II had there been more of them and had those that made it into the action had reliable engines.

The Germans needed about five years to get the Me 262 off the drawing board and into the air. It took more than twice that to get a copy up for its first flight, late in 2002. The first effort to make Me 262 copies, which began in the early 1990s and involved warbird fan Stephen L. Snyder and a Texas aircraft restoration company, dissolved in acrimony. Snyder called on Hammer to take over the work. The effort was barely under way when Snyder died in the crash of his North American F-86 jet fighter in 1999. Years of problems with engine generators, brakes, and landing gear assemblies followed.

"At times we thought this was stupid and should just give up," says Jim Byron, another retired Boeing executive who pitched in. "But that's not the Boeing mentality, so we kept plugging along."

Hammer and Byron—along with dozens of volunteers—worked doggedly on the difficult aircraft. Hammer is something of an aviation prodigy, a youthful-looking, sandy-haired 67-year-old who favors faded blue jeans and T-shirts. He spent 38 years at Boeing, working as chief engineer on the 757, among other projects. He has also built an array of aircraft in his spare time, most recently a four-seat Seafire amphibian that was named Grand Champion Seaplane at the 1998 Experimental Aircraft Association airshow in Oshkosh, Wisconsin. On the Me 262, he

The world's first combat jet flies again.

ORMBIRD

A NEWLY COMPLETED REPLICA of the Me 262 flies over Washington's Puget Sound (above) with a Consolidated B-24 Liberator bomber, a contemporary of the original jet fighter. Below: The original's prototype roared off a German runway 65 years ago.

LEFT NASM (SI NEG. #79-13831); ABOVE: JIM LARSEN

JIM LARSEN (2)

>>> THE ME 262 PROJECT ramp at Paine Field, Washington, began to resemble an old German airfield (above). The project proved a challenge even for Bob Hammer (right), who worked 38 years for Boeing.

handles most of the engineering challenges, while Byron, an avuncular 68-year-old with white hair, runs the office and manages the volunteer team.

The Me 262 Project is headquartered in a nondescript hangar at Paine Field, a large airfield north of Seattle. Aviation maintenance giant Goodrich has a facility there, and Boeing uses the field to roll out new 747s and 777s for their first flights after they leave the nearby wide-body plant. On the second floor of the hangar is a warren of offices and meeting rooms, the walls covered with Me 262 photographs and drawings. Downstairs, a crowded shop holds a completed Me 262 and more in assembly—wings, engines, and shelves of parts scattered around.

Hammer and his team took over the Me 262 project in late 1998, and their the first task was to finish *Vera*, a derelict Me 262 that Steve Snyder had found sitting outside the Willow Grove Naval Air Station near Philadelphia. *Vera* had been captured after World War II and flown as an experimental aircraft until it was sent to Willow Grove, where it sat on static display for many years. In exchange for the right to use *Vera* (the nickname came from the sister-in-law of a pilot who had helped capture Me 262s after World War II) as a template, Snyder had agreed to restore the aircraft to static-display quality. Snyder's death nearly ended the Me 262 Project. But Hammer

One of the Oldest Living Luftwaffe Veterans Tells All

FRANZ STIGLER WAS one of the lucky ones.

Out of 28,000 fighter pilots who flew for the Luftwaffe during World War II, only about 1,400 survived. Stigler was one of that small number, a feat all the more remarkable considering he was one of the pioneering pilots of the German air force's powerful but troublesome new jet fighter, the Me 262.

COURTESY FRANZ STIGLER

>>> AS A YOUNG PILOT, Franz Stigler was shot down 17 times, bailed out six times, and rode ailing Bf 109s in 11 times. He has logged 487 combat missions and has 10,000 flight hours in more than 100 kinds of aircraft, Allied included.

Stigler was an experienced pilot even before World War II. He flew supply planes during the Spanish Civil War, and when World War II began he was working as a flying instructor for the Luftwaffe. In 1940, his older brother, a night fighter pilot named August, was killed over the North Sea. August's death compelled Stigler to seek frontline duty, and by 1942 he was flying Bf 109s over North Africa while Field Marshal Erwin Rommel's Afrika Corps battled British and U.S. ground forces.

Stigler also flew in Italy and Germany. In early 1944 he was called to Lager-Lechfeld airfield in Austria to learn to fly the new Me 262, just coming off production lines. He then taught other pilots to fly the jet, and early the next year was called by General Adolf Galland — one of Germany's most prominent airmen — to join Galland's new JG 44, a group of Me 262 pilots that became known as the Galland Circus.

Stigler flew perhaps 60 combat missions in the Me 262 as massive Allied aerial bombardments gradually ground the Luftwaffe to pieces. He remembers the blazing speed of the Me 262, something that made him feel almost invulnerable to British and U.S. fighters. And when attacking bombers, the Me 262's formidable armament of four MK 108 30-mm cannons was devastating.

"We'd go high above them and then come down on the bombers," Stigler recalls, sitting in the den of his home in Surrey, British Columbia, an orange cat

NASM (SI NEG. #79-3257-13)

JIM LARSEN

>>> THE ORIGINAL ME 262 cockpit (above) got a minor facelift in the reproduction (right), with the addition of several new instruments, including modern radios and navigation gear (and air conditioning for the Arizona buyer).

talked with two buyers he had lined up for Me 262 reproductions—the Messerschmitt Foundation in Munich, Germany, and a retired judge in Arizona named Louis Werner—and they agreed to finance both the restoration of *Vera* and the construction of two reproductions of the old warplane.

The goal of the Me 262 Project was not to make an identical copy of the original aircraft; some concessions have been inevitable. The original Junkers Jumo jet engines, for instance, were famously prone to breakdowns and often good for no more than 10 hours of flight (although some built with higher quality steel reached a service life of 200 hours or more). So the engines used by the Me 262 Project are the reliable, proven GE J85 engines found on many business jets. The Me 262's nose gear was notoriously fragile, with the Germans losing many aircraft to nose wheel collapses. Hammer fashioned a brace for the gear that eliminated the problem. And all the aircraft have modern radios and navigation gear.

purring on the chair back. "A few hits were enough to blow the wing off a B-17."

Landings and takeoffs in the Me 262, however, were a nightmare. Allied pilots knew the jets were most vulnerable at those times because, if the throttles were advanced too quickly, the Jumo 004 engines would flame out. So P-51 Mustangs and Hawker Tempests would orbit over known Me 262 air bases, waiting for the right moment. "We were helpless then," says Stigler. Even when attacking bomber formations, the swarms of Allied fighters accompanying the bombers made it difficult to reach the B-17s and B-24s. In 1945, Stigler and perhaps a half-dozen Me 262s—along with propeller-driven FW 190s and Bf 109s—sometimes scrambled to face Eighth Air Force attacks of as many as 2,000 bombers and fighters.

Stigler shot down 28 Allied aircraft, with several more probable kills. He in turn was shot down 17 times, bailing out of six aircraft. He was also involved in one of those rare moments of humanity during war. On December 20, 1943, Stigler was flying a Bf 109 when he encountered a badly shot-up B-17 named *Ye Olde Pub*, piloted by 21-year-old Lieutenant Charlie Brown. Stigler let the crippled bomber go, and years after the war had a chance to meet Brown. Today, a painting commemorating their encounter in World War II adorns a wall in Stigler's den.

NICK CIRELLI

>>> FRANZ STIGLER, with his godson, Jim Berladyn, stands proudly in front of the airplane he helped make famous.

Stigler moved to Canada in 1954. Now 90, he lives with his wife, Hia, in Surrey, just south of Vancouver. He suffers from heart and hip problems. He has twice visited the Me 262 Project to watch progress on the reproductions of the jet he flew. "I almost cried when I saw one," he says.

The Combat Jet's Genesis

THE AGE OF JET COMBAT BEGAN on July 26, 1944. On that day, a de Havilland DH98 Mosquito reconnaissance plane flown by Flight Lieutenant A.E. Wall was attacked over Munich, Germany, by an extremely fast aircraft with a profile like a shark and sharply raked wings. Typically, in level flight the wooden, two-engine Mosquito could outrun anything. But now Wall was at the mercy of a mysterious German aircraft, which made repeated passes at him. Only frantic maneuvering and a nearby cloud saved Wall, who had flung his aircraft about the sky so vigorously in his efforts to escape that a door blew off.

Wall's nemesis was the Messerschmitt Me 262, a two-engine jet-powered aircraft that was utterly unique in design and performance. Although the Me 262 had the potential to rewrite the rules of aerial combat, it did little to alter the course of World War II. According to Richard Eger, a historian in Delaware who has amassed one of the world's largest Me 262 historical collections, Me 262s shot down about 445 Allied aircraft, while around 200 of the jets were lost in combat. Still, it has made an important contribution to aviation history. "The Me 262 brought aviation into the Jet Age, it's as simple as that," says Eger.

Research into jet engines had begun in the early 1930s in both Britain and Germany. The British won the race by firing up a gas turbine jet in April 1937. But the Germans pushed hard, and in August 1939 the little Heinkel 178 became the world's first aircraft to fly under jet power, propelled by a jet designed by Heinkel engineer Pabst von Ohain.

Initially, the Me 262 was to have been powered by turbojets from BMW. Those engines were slow in development, however, so the first Me 262 was tested with a piston engine in the nose. A second prototype carried the new BMW engines but kept the piston engine – a good thing since both BMW turbojets flamed out seconds after takeoff. Two Jumo 004 engines were fitted in their place, making the third Me 262 a true jet aircraft; it made its first flight under all-jet power on July 18, 1942. The Jumos were the first axial-flow jet turbines, in which air flows from the front to the back of the engine while it is squeezed by compressor fans and mixed with fuel. The Jumos were also the first jet engines to enter mass production.

As novel as the engines were, the airframe of the Me 262 was equally unusual. The sweep of its wings was the result of earlier German research into this design, which reduced drag while allowing a wing thick enough to be practical. Willi Messerschmitt, founder of the aircraft company that bore his name, did his own research in this area. His new jet-powered aircraft had wings that angled back 18 degrees.

The Me 262's tricycle landing gear, which was designed to retract into the fuselage due to lack of room in the wings, resulted in the aircraft's distinctive triangular cross-section. And uncertainty over the final size of the engines resulted in engine pods – designers simply stuck them under the wing.

Once the Me 262 entered combat, it astonished Allied pilots with its speed, easily flying 100-plus mph faster than anything flown against it. The Me 262's top speed was around 560 mph, versus about 440 mph for the P-51, which along with the British-made Hawker Tempest was perhaps the fastest Allied fighter in Europe. "We found it impossible to climb with

>>> *VERA*, IN HER ORIGINAL glory, leads a group of Me 262s (below), captured by the U.S. Air Force, as they taxi for takeoff from the airfield at Lechfeld, Germany, in 1945.

NASM (SI NEG. #78-17901-15)

NASM (SI NEG. #79-7222)

JIM LARSEN

>>> THE UNRELIABLE JUMO ENGINES (left) were replaced with less temperamental GE J85s (above), ordinarily found on business jets.

them, and expended much fuel trying," one P-51 Mustang pilot recounted after fruitlessly chasing four Me 262s in February 1945.

But the Me 262 also had several Achilles' heels. It was so fast that the control stick was heavy due to air pressure on the rudder, elevators, and ailerons. Without hydraulic boost in the controls, the Me 262 didn't turn well and was a poor dogfighter. And although as few as three or four hits from the Me 262's four powerful 30-mm cannons could bring down a four-engine bomber (a single hit could blow apart a British Spitfire), few pilots could manage to put a bomber in their sights during the few seconds they had to aim.

Most seriously, the Me 262 was vulnerable at takeoff and landing because its pilots had to carefully control fuel supply. German engineers, meanwhile, faced shortages that forced them to build the Me 262's Jumo engines with steel for the vital compressor blades instead of tougher metals such as chromium. If the pilots had a delicate touch on the throttles, the engines held up fairly well, but in the heat of battle it was difficult to stay calm. The result was that engines had to be replaced after as few as 10 hours of flight time, and pilots flying the Me 262s were plagued with flameouts and turbine blades that disintegrated in flight.

If the Me 262 had become fully operational in 1943 rather than 1944, the aircraft might have blunted the Allies' bombing campaign. But change the outcome of the war? Not likely, say historians. Aviation historian Daniel Uziel believes the Me 262 actually hindered the German war effort. The Germans, argues Uziel, underestimated how difficult it would be to develop an entirely new aviation technology and train pilots to use it. Nor did they anticipate the challenges of mass-producing the Me 262. They did manage to produce about 1,430, but only 300 reached active duty.

Still, the Me 262 continues to intrigue and captivate — a fearsome-looking yet elegant aircraft that awed its wartime foes.

Overall, though, the team has stuck as closely as possible to the real thing. While aluminum would have been lighter, the skin was made of steel, like the skin on the originals—a concession to wartime aluminum shortages. The instrument panel was made from plywood, as were the landing gear doors. The use of Phillips-head screws seemed like a reasonable substitute, but guests from the Messerschmitt Foundation, who planned to make a flying copy of the Me 262 the centerpiece of their collection of Willi Messerschmitt-designed airplanes, insisted that slotted screws, identical to those in the original, be used. "We only need 500, but had to buy 15,000 of them," Byron chuckles, comparing his request for slotted screws to walking into a modern RadioShack and asking to buy television tubes. "They said 'We'll do it,' but once they set up to make slotted-head screws, they had to crank them out like yards of sausage."

Hammer's group needed nearly four years to transform its pile of parts into a flying Me 262. Problems abounded. At one point, for instance, the team was confounded by the controllers for the engine generators, which provide electricity to the aircraft. "It was the worst kind of problem—an intermittent one," says Hammer. The controllers would occasionally burn out a relay for no apparent reason, shutting down power to the aircraft. "It was driving me nuts." Finally, Hammer found a retired electronics engi-

NICK CIRELLI

***>>> WHITE ONE*'s rear canopy is installed by John Callison (left). The Me 262 B-1c is a two-seat model — the c designation refers to the J85 engines on the reproduction aircraft.**

NICK CIRELLI

>>> A J85 ENGINE can receives special attention from Mike Harris and project volunteer Jim Hacker.

neer who agreed to pore over the controllers' complex wiring schematics ("They looked like a road map from here to Greece," says Hammer). After two days, the engineer unearthed a fault in the original Air Force wiring diagram, which caused the project team to miswire the controllers.

The team also faced headaches in getting the brakes to work properly (modern disc brakes replace the failure-prone drum brakes on the original), and in balancing the 2,500 pounds of thrust from the GE J-85 with the flying characteristics of the Me 262, which was designed for a less-powerful engine. "People think that once you have an airframe, you're 90 percent of the way there," says Hammer. "Hell no. That's only about 15 percent.... The rest is integrating all the rest of this stuff so it works together."

NASM (SI NEG. #7A-49424)

>>> BAD ATTITUDE: Nose gear fragility was often the cause of fiery crashes on landing (left). Garrett Downing works on a more robust landing gear for *Tango-Tango* (below).

JIM LARSEN

Hammer came to greatly admire the Stormbird. The name (*Sturmvogel* in German) refers to the fighter-bomber version of the aircraft, but seems more fitting than the fighter's name, *Schwalbe*, which means Swallow. "I was really impressed with the way the airplane was designed for easy assembly," he says. "They were building this thing in woods and caves and everywhere else, so parts were built all over the place and then put together." The cockpit "tub," for instance, was a single assembly that could be dropped into a fuselage. Wing and control components were similarly designed for easy construction and assembly.

Finally, on December 20, 2002, aviation history was made...again. Wolfgang Czaia, a former pilot for the modern German Luftwaffe (Czaia still flies Lockheed F-104 Starfighters as part of the Starfighters Airshow Demonstration Team) and a retired 757/767 captain for American Airlines, flew an Me 262 dubbed *White One* at Paine Field. For 35 minutes, Czaia made gentle turns and tested the airplane's stall characteristics while keeping the gear down. "A pleasure to fly," Czaia wrote in his flight test report. "Overall, a great first flight."

On the next flight, January 18, the gear was retracted. Right away Czaia had problems, with two red lights on his instrument panel. An observer in a chase airplane reported the gear up and doors closed. Czaia cycled the gear again. This time the nose wheel dropped only part way while the main gear stayed up. Finally, he activated an emergency system that used compressed nitrogen to blow the gear down. Success—or so Czaia thought.

As Czaia touched down, the main landing gear on the aircraft's left side collapsed. Within seconds, the speeding Me 262 had careered off the runway and over an embankment. "That was a pretty rough ride," recalls Czaia. "CNN had a camera in the cockpit that day and caught the whole thing."

The horrified ground crew dashed to the crash site

JIM LARSEN

>>> *TANGO-TANGO* takes a joyride over the North Cascade mountain range in Washington state. Mount Baker is in the background.

and found Czaia clambering out of the jet, unhurt. The airplane wasn't so lucky. In addition to the collapsed gear, one wing was crunched and the engine nacelles had substantial dents.

The team eventually traced the problem to a landing gear actuator assembly that had been machined slightly out of tolerance in Texas. The gear had performed flawlessly during hundreds of ground tests, but the stress of an actual landing caused it to buckle. Within a week, Hammer had tracked down an original landing gear actuator and started work on duplicating it.

By the summer of 2004, *White One* was flying again—this time without any problems. The second Me 262, *Tango-Tango*, was completed in the summer of 2005, and last fall was disassembled and flown to Munich, Germany, in a 747 freighter, where it was the hit of the Berlin Airshow. *Tango-Tango* also flew for a Family Day at the Messerschmitt Foundation. Organizers expected 3,000 people; 90,000 showed up. A third aircraft should be flying this fall, with the last two scheduled for completion when the Me 262 Project finds buyers.

After that, no additional Me 262s will be built. During the breakup between Steve Snyder and the Texas company that first worked on the aircraft, several key jigs for making wings and fuselages were lost, so the Everett group lacks the tools needed to build one from scratch. Instead, they're tackling the restoration of a piston-powered fighter, a Messerschmitt Bf 109F that had crashed in Russia during World War II.

Meanwhile, the Me 262 Project still has three Me 262s for sale at about $2 million each. "It took far longer and cost far more money than I ever would have imagined, but we got here," says Hammer.

SEE THE Me 262

NATIONAL AIR AND SPACE MUSEUM, Washington, D.C. The NASM Me-262A-1a (the single seat version) was found at Lechfeld, Germany, in 1945 by a special U.S. Air Force team. The team had been charged with capturing advanced German aircraft in a mission known as Operation Lusty. The Me 262 arrived at the Silver Hill, Maryland, facility in 1950, and restoration began in 1978.
www.nasm.si.edu

NATIONAL MUSEUM OF THE UNITED STATES AIR FORCE, Dayton, Ohio. The Me 262 on display in Dayton was also brought to the United States in 1945 as part of Operation Lusty. Between 1976 and 1979, this aircraft was restored by the 96th Mobile Maintenance Squadron at Kelly Air Force Base in Texas.
www.nationalmuseum.af.mil

ERIC LONG/NASM

The National Air and Space Museum's Me 262 is on display in the Jet Aviation Gallery. Its markings are those of the JG 7 (Fighter Wing 7).

BRENNAN LINSLEY/AP

SPACE IMAGING EURASIA

LOOKING OUT THE WINDOW DURing final approach, you see the flaps extend and feel the landing gear drop down and lock into place. The aircraft rolls abruptly and begins spiraling downward like a slowly turning bit in a power drill. By the time you figure out what's happening, the wheels touch ground with a reassuring thud and the airplane rolls to a safe stop on the runway.

What was *that*?

Before jumping out of your seat to complain to the pilot, consider the good news: You've just avoided being shot down by a missile. Welcome to Baghdad International Airport.

Hundreds of civilian aircraft take off and land at Baghdad International every week. These aren't the friendliest of skies, however. Outside the heavily defended airfield perimeter are bands of insurgents who occasionally target civilian and military aircraft with surface-to-air missiles. To avoid being knocked out of the sky, pilots employ an old, trusted tactic: the spiral, or corkscrew, landing approach. Once the plane arrives at about 18,000 feet—still safely beyond the range of weapons like the SA-7 shoulder-fired missile—the pilot banks sharply and descends toward the runway in a slow, tight circle, like someone walking down a spiral staircase. During the spiral the crew keeps an eye out for other air traffic, and for anything coming at them from the ground. After several turns, the pilot pulls out of the rotation with careful timing, straightens out, and lands. The whole thing takes seven to 10 minutes, roughly the same as a regular approach, but it all takes place directly overhead, instead of beginning 20 miles from the runway.

Though it sounds like something from a flying circus, the corkscrew is actually a straightforward tactic that uses fairly standard piloting skills. Airline pilots sometimes use a similar maneuver, descending quickly through clouds to get under bad weather. With a little on-the-job training, spiraling down to the runway becomes second nature, says Kurt Neuenschwander, international chief pilot for Air Serv International, a nonprofit organization that flies relief workers and supplies into Iraq. Landing in Baghdad, he has flown Embraer 120s, which can handle a maximum bank angle of 60 degrees. Neuenschwander keeps it under 55 to be safe.

Initially the spiral was used only sporadically by pilots flying into Baghdad, until a near-disaster in November 2003 convinced everyone to give it a second look. A shoulder-fired missile ignited a fuel tank on a DHL Airbus A300 cargo jet that had just left the runway. The resulting fireball set the left wing ablaze and knocked out all hydraulic systems. With thick funnels of smoke pouring from their airplane, the crew used engine thrust to control the aircraft, turn it around, and make an emergency landing—just barely. It was a remarkable feat; the pilot had recalled the experience of Al Haynes, who managed to land his United Airlines DC-10 without hydraulics in Sioux City, Iowa, in 1989 using only engine thrust. Since the DHL incident, most pilots flying into Baghdad have adopted the corkscrew as a standard evasive maneuver, even though it isn't required.

No one's quite sure where or when the corkscrew maneuver originated, but the tactic dates at least to the Vietnam War. "The spiral has been used for years into airports that have been secured militarily," says Paul Botha, chief pilot for AirQuarius, a South African firm that operates twin-engine Fokker F28s for Royal Jordanian Airlines. "I first became aware of it during the war between South Africa and the South West Africa People's Organization in Namibia during the 1980s." Neuenschwander flew the corkscrew to avoid small-arms fire during the Sudanese civil war in 1994. "We were flying relief operations in and out of the country," he says. "In many villages where we landed, rebel forces were within a mile and knew that we were coming."

However nerve-wracking the corkscrew landing might sound, Botha says it isn't terribly exciting for pilots. "Some of our captains call it boring, because you are flying in circles," he says. But for passengers, particularly those making their first

ING IN BAGHDAD

At the world's most dangerous airport, it's best to get down quickly. by Allan T. Duffin

landing in Baghdad, the corkscrew can be intimidating. "You have no forward-looking vision," notes Neuenschwander, "so if you're looking out the side windows, you're seeing either the sky or the ground. A lot of people tense up, especially if they don't have much flying experience." Flying into Baghdad on an Air Serv aircraft, journalist Betsy Hiel recalls "a woman across the aisle gritting her teeth so hard that she snapped one tooth off."

For frequent fliers, the spiral descent actually has aesthetic advantages. "Coming in on a corkscrew affords a great view of Baghdad and of the airport," notes Thanassis Cambanis, who has flown in and out of Iraq more than a dozen times on assignment for the *Boston Globe*. "To me, the plane doesn't feel like it's descending any faster than usual, so it's not too frightening." And compared to the prospect of a missile taking down your airplane, any landing, even a wild corkscrew ride, can be downright comforting.

DHL

In November 2003, Iraqi insurgents fired a missile into the left wing of a DHL cargo craft (above); the crew of three survived a rough landing. Today, pilots like Robert Brand (opposite), landing an airliner at Baghdad International Airport, use a spiral pattern to evade ground fire.

MICHAEL MOSES REMEMBERS feeling giddy that day in February 2005 as he walked into chief flight director Milt Heflin's office at NASA's Johnson Space Flight Center in Houston to accept his new job. Among space engineers, becoming a flight director is a crowning career achievement, and Moses half-expected Heflin, known as Uncle Milty, to give a round of high-fives to the nine newly selected directors gathered in the room. But Heflin's words were sober. "We got an hour-long lecture that this is dangerous business, that we are on the pointy end of the sword, and that if we screw up, somebody dies," Moses recalls.

Not exactly welcoming, the lecture at least had an impact. "That night I hardly slept," says Richard Jones, who like Moses had worked for years in mission control before being promoted to flight director. Another new flight director, Holly Ridings, whose previous job in mission control had been monitoring the attitude of the International Space Station (ISS) in orbit, says that now, "every time I sit down in the flight director chair, there is a little piece of my mind that thinks, 'If things go really wrong today, the U.S. space program could be over—or at least grounded for a very long time.' "

Months later, when I asked Heflin why the shock treatment was necessary when all the new recruits were already battle-hardened veterans, he answered, "Humility was something they needed to pay attention to right away. They could not leave pounding their chests."

For one thing, he says, "there were a number of people who weren't in the room [who] were just as qualified to be sitting there with them." And the new directors will still rely heavily on those people's judgment. The flight director sees the big picture during a spaceflight, but it's the individual flight controllers sitting at 19 consoles—from the propulsion engineer to the booster systems engineer to the flight surgeon—who supply the critical details. Moses, Jones, Ridings, and all but one of the other new flight directors had been reared as NASA flight controllers, in fact. Last year, a spate of retirements and promotions in mission control freed up nine coveted slots for flight director, bringing the total number to 30. It was the second largest collective hire since the job was created in the early days of the space program.

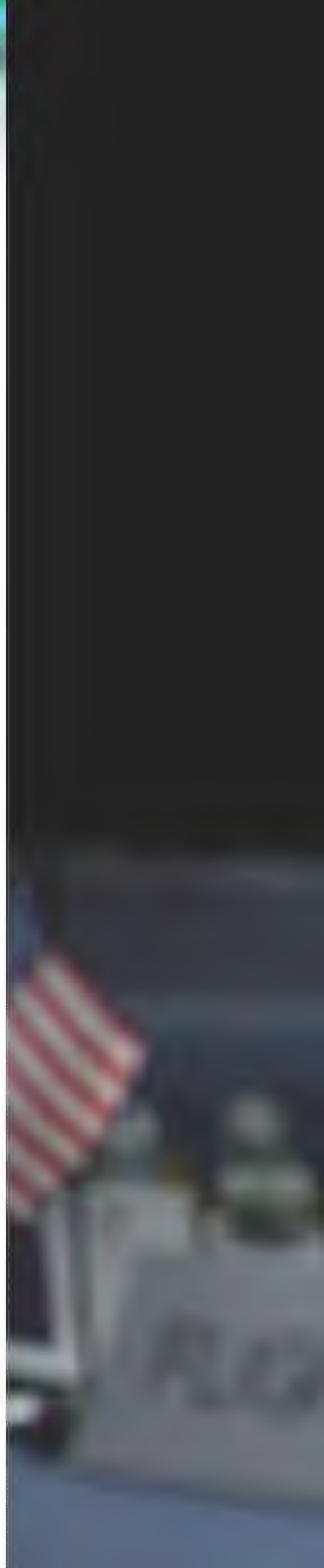
A quick demographic profile of the Class of 2005: Six men and three women, all but one in their 30s. Three native Texans, four from northeastern states, two from the Midwest. The class includes the first African-American flight director, 34-year-old Kwatsi Alibaruhu of Maywood, Illinois, an MIT graduate who joined NASA in 1995 as a space station life support systems officer. And while most of the nine have engineering degrees, 43-year-old Robert Dempsey, a former space station controller for communications and tracking, is also an astronomer, having worked at the Space Telescope Science Institute in Baltimore in the early 1990s. All are whip-smart, and all are high achievers.

Last December I spent a day at JSC with the new recruits as they went through their training exercises. By 7:30 a.m., Dempsey is already "on console" in the Flight Control Room (FCR, or "ficker") for the space station. He hands me a set of headphones so I can listen to the comm loop, an open channel between mission control and the orbiting astronauts.

The station ficker is called the Blue Room. There's also the Red Room, used for ISS training, and the White Room, the shuttle ficker, the room Hollywood usually depicts in films. Today's task in the White Room is a simulated docking between the shuttle and the station, with new flight director Michael Sarafin in charge. Before his promotion Sarafin worked in mission control for 10 years as a guidance, navigation, and control officer. He was on duty during the 2003 *Columbia* accident, but doesn't seem eager to discuss it, at least not with a journalist. "It was a hard day to lose our friends" is all he says.

In today's scenario, the shuttle (a simulator in another room) will perform a two-minute burn of its twin Orbital Maneuvering System engines. The aim is to boost the vehicle into a higher orbit to rendezvous with the station. Two floors

BY MICHAEL BEHAR



Tough under pressure: Space station flight director Mark Ferring at his console during last year's STS-114 mission.

ALL PHOTOGRAPHS: NASA

ASTRONAUTS GET THE GLORY, BUT FLIGHT DIRECTORS RUN THE SHOW.

The GROUND

above, the simulation supervisor, or "sim-sup," and his cohorts will try to confound the flight controllers with any number of curve balls. "They might cause a fire, cabin leak, loss of communications, loss of critical flight control systems, or loss of jet thrusters," says Sarafin. "They are pulling the puppet strings behind the scenes. Our job is to react to what they do."

The engines fire and mission control falls silent. The exact positions of the shuttle and ISS are projected as a high-resolution graphic on a 10- by 12-foot overhead screen. Another large display plots the orbit of the shuttle and station onto a world map. A third screen relays telemetry data, caution messages, and emergency warnings from the shuttle and ISS to mission control. It's only a simulation, but I'm transfixed by the realism, knowing that all hell is about to break loose. Suddenly, a yellow warning code indicates three separate temperature spikes in one of the avionics bays that house the shuttle's flight control and computer systems. The EECOM (emergency, environmental, and consumable operations manager), pronounced "ee-com," calmly flips through her mission rulebook ("Our bible," says Sarafin) to find the right protocol and determines—with the help of other flight controllers—that the spikes are caused by a small blockage in the water-cooling loop. Switching to a redundant cooling loop returns the temperatures to normal.

It's this particular EECOM's first simulation in the ficker front room, a significant milestone for a flight controller. She's already endured hundreds of similar exercises in the "back room," where junior flight controllers work in specialist teams, training on each system in year-long rotations like med school students alternating between the psych ward, gastroenterology, and pediatrics. So goes the arc of a career in mission control—back room to front room to flight director.

Shuttle simulations might last three or four days, and to get certified to work an actual launch and landing, a flight director may have completed hundreds of simulations before doing it for real. "They give you all these failures—to the point where it is almost unrealistic—to see how we'll react," says Ridings.

Still, even after hundreds of hours of practicing far-fetched disaster scenarios, real missions occasionally serve up surprises. One frequently cited by flight directors is the March 1992 STS-49 mission to rescue an Intelsat communications satellite stranded in an unusable orbit. The shuttle crew's task was to attach a new rocket motor to the satellite that would boost it to the proper altitude. The original plan had been for a spacewalking astronaut at the end of the shuttle's robot arm to snare the satellite with a special capture bar and bring it into the shuttle cargo bay. When that failed several times, the astronauts themselves proposed a workaround: Send out three spacewalkers, which had never been tried before, to grab the two-ton beast by hand and coax it into the bay.

Former chief flight director Milt Heflin (standing) tells new hires the unvarnished truth: "If we screw up, somebody dies."

It worked. But after the astronauts attached a booster rocket to the satellite and reentered the shuttle, another glitch occurred. When the crew flipped a pair of switches to activate a spring that would eject the satellite from the shuttle, nothing happened. "Now we're sitting there with a satellite in our payload bay, with a rocket motor that might be getting ready to fire off," recalls Phil Engelauf, who was a flight director for the mission.

Stumped by a potentially dangerous situation they'd never trained for, the ground controllers set to work. Engelauf remembers Jeff Hanley, then a mission control payload officer responsible for the vehicle's cargo, poring over the shuttle's wiring diagrams. "He was sitting in front of me with these long, fold-out drawings tracing through the entire system," says Engelauf. Hanley had a hunch: The arming and firing circuits could have been wired backward. "Instead of arming the A circuit and firing the B circuit, Hanley wanted to arm the B circuit and fire the A circuit. So we read the instructions up

to the crew and I remember you could cut the tension and suspense with a knife as we counted down...three...two...one...fire... and sure enough, the satellite left the payload bay."

Intuition like Hanley's amounts to a sixth sense, says Gene Kranz, the legendary NASA flight director who handled mission control's most famous "save" after an oxygen tank on the Apollo 13 spacecraft exploded on the way to the moon in 1970. "There's a gut feeling, an almost intuitive response to things that are happening around you," he says. "It's like chess," says former astronaut and NASA head of spaceflight Bill Readdy. "You have to always think several moves ahead."

So it was with an emergency on the space station on Super Bowl Sunday, February 3, 2002. When a software glitch took down the station's Russian-run computers shortly before midnight, there wasn't much Bryan Lunney, the flight director

Displays in mission control have gotten more user-friendly since Apollo, but the stream of data can still be hypnotizing.

on duty, could do but watch and wait. The Russian computers fed data to the station's gyroscopes, which were essential for holding the station's position stable. Two hours after the first computer failed, the backup system also crashed. "We'd seen similar things in the past," says Lunney, whose father was the Apollo-era flight director Glynn Lunney. "It's normally no big deal. But when the second computer failed, we started thinking about what to do if the third one failed too."

Sure enough, the third computer also shut down. With data no longer being supplied by its gyroscopes, the ISS began a very slow tumble. Consequently, the huge solar arrays were no longer pointing at the sun. And without a steady supply of solar-derived electricity, the controllers knew things would get dark and cold pretty fast. "If the station runs out of power, that's bad," says Lunney. "There is no good way to jumpstart it."

Not sure how long the computers would be down, and never having trained for a triple-computer failure, Lunney turned for help to his PHALCON (power generation, storage, and power distribution) flight controller, who offered a simple, almost primitive solution: Have the crew look out the window, find the sun, then manually rotate the arrays toward the light. "He came up with this procedure on the fly," says Lunney. "It had never been done before."

The PHALCON controller devised a crude table that divided the station into four viewing areas—deck, forward, overhead, and aft—with corresponding angles for each section. For example, if the sun was visible through the aft portal, the crew should tilt one solar array to 90 degrees and the other to 270. Because radio communications on the drifting station were also intermittent, mission control would have less than five minutes to read the instructions up to the astronauts. "We practiced reading it aloud a couple of times to see how long it took," remembers Lunney. "I was nervous and the adrenalin was certainly flowing." But the solar arrays eked out enough juice to keep the station powered up until the Russians finally got their computers back online. Visible relief swept through mission control. Says Lunney, "I felt like a fireman who'd walked out of a burning house having just rescued the kids from the bedroom."

Although the improvised procedure worked, space engineers hate to wing it when astronauts' lives and billions of dollars of hardware are at stake. That's why flight directors are among the most systematically and thoroughly trained professionals in any field. "They are Spartans, tough and competent, like the Navy SEALs," says Ron Dittemore, the now-retired flight director who was in the public spotlight as NASA's shuttle program manager at the time of the *Columbia* accident.

"PEOPLE CALL YOU AT TWO IN THE MORNING, OR ON VACATION, IT DOESN'T MATTER," SAYS RIDINGS. "WHEN YOU'RE WORKING A BIG MISSION, YOU GET HOME AFTER A SHIFT AND IMMEDIATELY TURN ON NASA TV. IT'S ADDICTIVE."

It was Gene Kranz who first scribbled "tough and competent" on a mission control chalkboard after another disaster—the fire that killed Apollo 1 astronauts Gus Grissom, Ed White, and Roger Chaffee during a ground test in 1967. Kranz demanded that flight directors write the words on the blackboards in their offices, never to be erased. That combat mentality—Kranz was a fighter pilot before joining NASA—engenders camaraderie and

mutual loyalty that extend well beyond working hours. "We knew each other very personally as a family," Kranz says of his time at the space agency. "We partied together. We had the largest party fund in all of the federal government. We would take over the Astrodome. It basically helped us maintain our bond." Not much has changed. "Being a flight director is not a job but a lifestyle," says Ridings. "You know everybody's kids, wives, and husbands. People call you at two in the morning, or on vacation, it doesn't matter. When you're working a big mission, you get home after a shift and immediately turn on NASA TV. It's addictive."

It's also demanding. The job is grueling mentally, and the nine-hour shifts go round the clock. Flight directors regularly have to adjust their sleep schedules. "Everyone has a really good set of blinds at home," quips Dana Weigel, who was a flight controller for extravehicular activities (spacewalks) before she was promoted to flight director.

The key to success, Sarafin explains, is learning how to handle potentially debilitating stress. He describes a condition called "scope lock" that sets in when a frazzled flight director or controller gets too focused on the minutiae of a particular problem "and forgets that there is a spacecraft flying up there." They lose sight of the big picture, hypnotized by the dizzying stream of data spewing from their consoles. "Others start to ramble when the pressure is on," adds Sarafin. "Or they might just stop talking entirely."

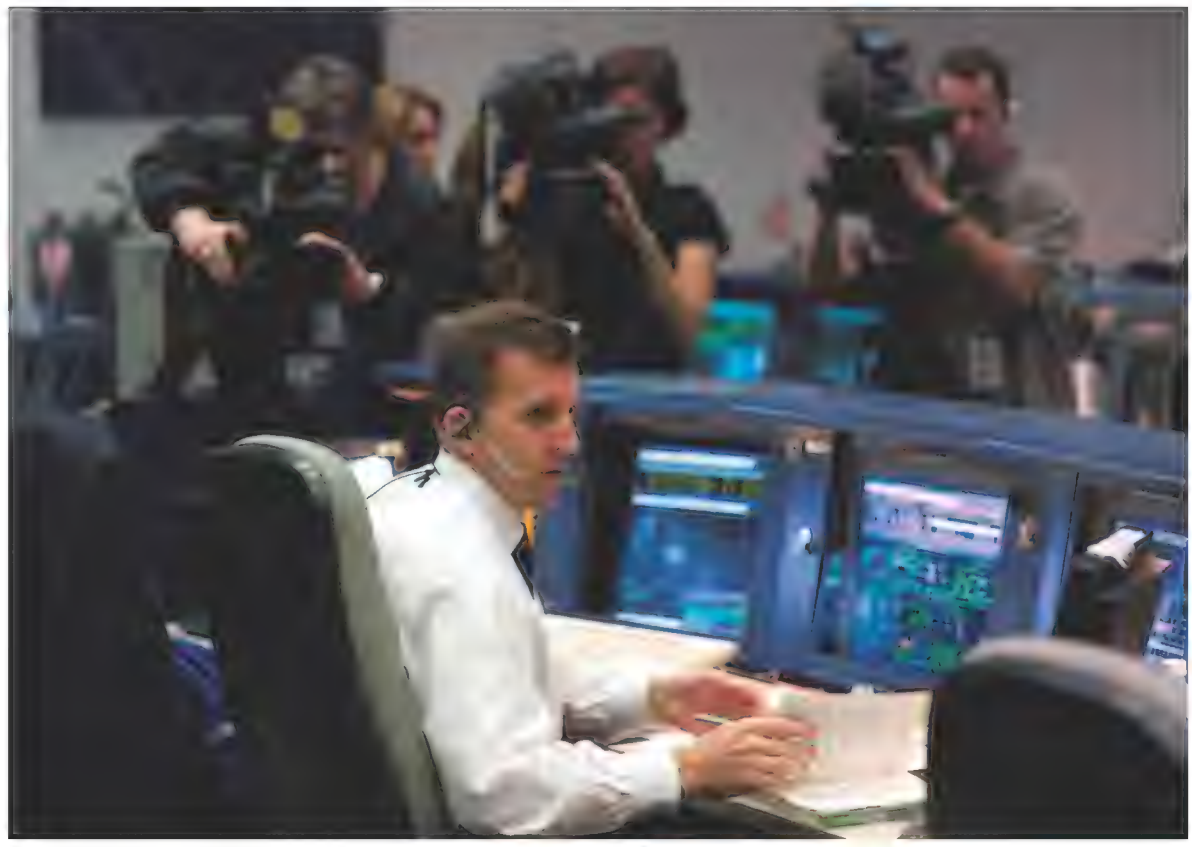
Burnout is a danger in most high-stress professions. For flight directors, it's endemic. The attrition rate for all flight controllers is in excess of 20 percent, says Sarafin. That's why, according to Heflin, the flight director culture has had to become more "touchy feely" than it was in the Apollo days—being driven is okay; being obsessed is not. "When I was chief of the flight director office [he was recently promoted to deputy director of NASA's mission operations directorate], I made a point of keeping track of how many hours they were working," says Heflin. "If I needed to, I'd tell them to slow down, to go home, and find a way when they get in their cars at the end of the day to leave the job behind." Not everyone makes it through unscathed. "The divorce rate within the flight director community is fairly high," Sarafin says.

For the Class of 2005, the job of flight director is about to change radically. Fewer than 20 shuttle missions remain before NASA's 25-year-old workhorse is retired. The agency has already begun to shift its focus from flying in Earth orbit to returning astronauts to the moon by 2020 and, someday, heading on to Mars. Not since Kranz ran the Apollo missions have flight directors faced such daunting missions.

This time, when it comes to directing the astronauts, they aim to be less...well, *controlling*. The purpose of NASA's new moon program is to stay for the long haul—to learn how to live on the lunar surface. That will mean rethinking the crew's relationship with mission control. "Right now we schedule the crew's time in five-minute chunks," says flight director Ginger Kerrick. "We know that's going to have to change."

Dempsey has been involved in planning an exercise for an upcoming space station mission "where we say to the crew, 'Okay, here are the key things to get done, here are your time constraints, now you plan it yourselves.' " The idea is to give the astronauts the freedom they'll need for lunar missions lasting months or even years.

An important part of this approach will be onboard autonomy, software systems that enable the crew to resolve a crisis when lengthy communications delays—in the case of Mars, up to 22 minutes, depending on the positions of the planets—make it impossible to talk to the ground in real time. "Instant problem resolution will have to fall on the astronauts' shoulders, not ours," says Dempsey. "When there's an onboard fault, it can't just be a



Left: Flight director LeRoy Cain during a 2005 simulation. Mission control is in the media spotlight more than ever following the *Columbia* accident. Above: By tradition, astronaut "capcoms" like Barbara Morgan and Michael Massimino are the ones who talk to crews in orbit.

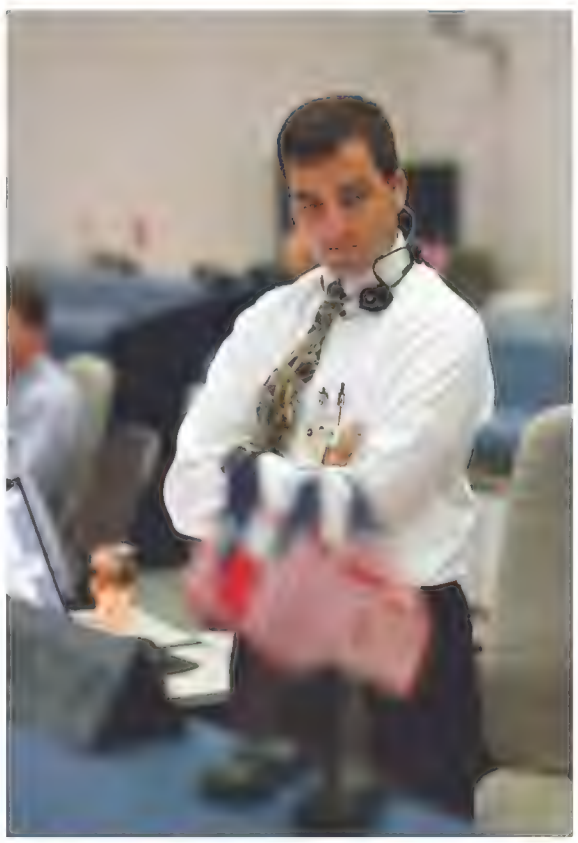
light that turns on. Today, when that light comes on, the guy sitting next to me tells the crew what page of what book to turn to. In the future, the software systems will have to do that for them."

Both Dempsey and Dittemore, who retired from NASA shortly after the *Columbia* accident, make the inevitable comparison to HAL 9000, the omnipotent, omnipresent computer in *2001: A Space Odyssey*. "Of course the system wouldn't be psychotic," assures Dempsey, "or necessarily super-intelligent, or even completely autonomous. But smarter than the software we have now." Dittemore says that some small steps have been taken in this direction, such as the Integrated Vehicle Health Monitoring system, flown on shuttle mission STS-95 in October 1998. IVHM uses a network of pressure, temperature, strain, and other sensors to monitor the vehicle's condition without aid from mission control, and even to do some limited troubleshooting.

The nine new flight directors are helping to plan the next generation of NASA space vehicles, even while their main responsibilities still lie with the shuttle and space station. I accompany Weigel and another new director, Brian Smith, to a meeting with the deputy project manager for the Crew Exploration Vehicle, or CEV, the upgraded Apollo-style capsule that will ferry astronauts to the moon and back beginning in the next decade.

We gather around a circular table inside JSC's Building 9, a massive hangar that houses, among other things, a life-size training mockup of various space station modules. When we arrive, instructors are conducting a simulation of a cabin fire, complete with billowing white smoke and blaring alarms. Directly behind us is a metal skeleton of the CEV, the framework for a full-scale model. For now, it's empty except for a pair of fuzzy dice dangling from its ceiling.

KRANZ EQUATES HANLEY'S INTUITION TO A SIXTH SENSE. "THERE'S A GUT FEELING, AN ALMOST INTUITIVE RESPONSE TO THINGS THAT ARE HAPPENING AROUND YOU," HE SAYS. "IT'S LIKE CHESS," ADDS READDY. "YOU HAVE TO ALWAYS THINK SEVERAL MOVES AHEAD."



Flight director Paul Hill weighs his options during STS-114.

The purpose of the meeting is to solicit from the flight directors specific suggestions for the spacecraft's interior layout, software systems, and other design features. Being in on these early decisions should give flight directors a tremendous advantage downstream, says Kranz, and will make them "far better at coping with the complexities of the new exploration program." He points to the colorful console displays that allow flight directors and flight controllers to keep tabs on every system in the spacecraft, such as navigation, guidance, communications, payload, life support, software, and extravehicular activity. Instead of strings of numbers, the modern CEV displays have easy-to-interpret graphics. "It gives flight directors a three-dimensional visualization of what's going on," says Kranz. "With Apollo 13, it took us almost 25 minutes to figure out we had an explosion. Whereas in today's world, they would have known it instantly."

But improved or not, these are still just tools. For the foreseeable future, flight directors will continue to rely on their own intuitions and instincts more than on technological wizardry. "It's the human element that allows them to be successful," says Readdy. The danger is in losing sight of that, of relying too much on technology. During the 1990s, when the shuttle was flying several times a year, he says, "there was an attempt to depersonalize the flight director's job. It wasn't about the people; it was about the science and the hardware." It all got "antiseptic and routine," he observes.

Even as they drill endlessly, routine is something the flight directors try to avoid. When it comes to spaceflight, a sense of routine can lead to trouble. "I'm not going to sugarcoat it," says Jones. "Ronald Reagan deemed the shuttle operational after the third or fourth flight. 'Operational' means we have nothing else to learn about the vehicle. That set a tone. Apathy set in. And NASA got in that mode that leads to accidents."

Being a flight director, says Kranz, is "about staying on the edge," always mindful that the U.S. space program could come to a halt because of something that happens on your next shift. No wonder, then, that Milt Heflin's "Welcome to your new job" speech was so somber.

How Things Work:

Aircraft Id

BY LESTER A. REINGOLD | ILLUSTRATION BY HARRY WHITVER

AIR TRAFFIC CONTROL WITHOUT RADAR? THOSE FAMILIAR TOWERS, OFTEN 40 FEET HIGH AND TOPPED WITH 20-BY-10-FOOT ROTATING ANTENNAS, MAY GRADUALLY GIVE WAY TO GROUND UNITS THE SIZE OF DORM ROOM REFRIGERATORS.

These devices will be part of a system known as Automatic Dependent Surveillance-Broadcast (ADS-B), and they're far cheaper than radars to build and maintain. System advocates promise other benefits, such as an increase in the U.S. airspace's traffic capacity.

Those fridge-size ADS-B ground facilities are virtually devoid of moving parts because, unlike traditional radar units, they have no need to sweep the sky to transmit radio waves and then gauge their return. ADS-B units can be mounted on cell phone towers and many other kinds of structures, and in remote sites that couldn't logistically accommodate big radars. Test programs are already placing them in the interior of Alaska and on oil platforms in the Gulf of Mexico. Airplanes equipped with ADS-B can also exchange data, conferring to pilots awareness of airspace now available only in the control tower.

ADS-B gets its position information from navigation systems on the aircraft, primarily the satellite-based Global Positioning System, or GPS. The typical airliner's Flight Management System (FMS) also includes other navigation aids that can back up the GPS, such as the Inertial Reference Unit, which relies on ring-laser or fiber-optic gyros.

To understand the significance of ADS-B, it helps to know a little about what it's replacing. With the most basic, or primary, radar, a rotating transmitter sends out high-power radio waves, which bounce off the target and return. The system notes where in the 360-degree sweep the target registered, which translates into the target's azimuth. The time it takes the radio waves to reach the target and return indicates its distance from the transmitter, or its range. With those two coordinates, the target is pinpointed in two-dimensional space.

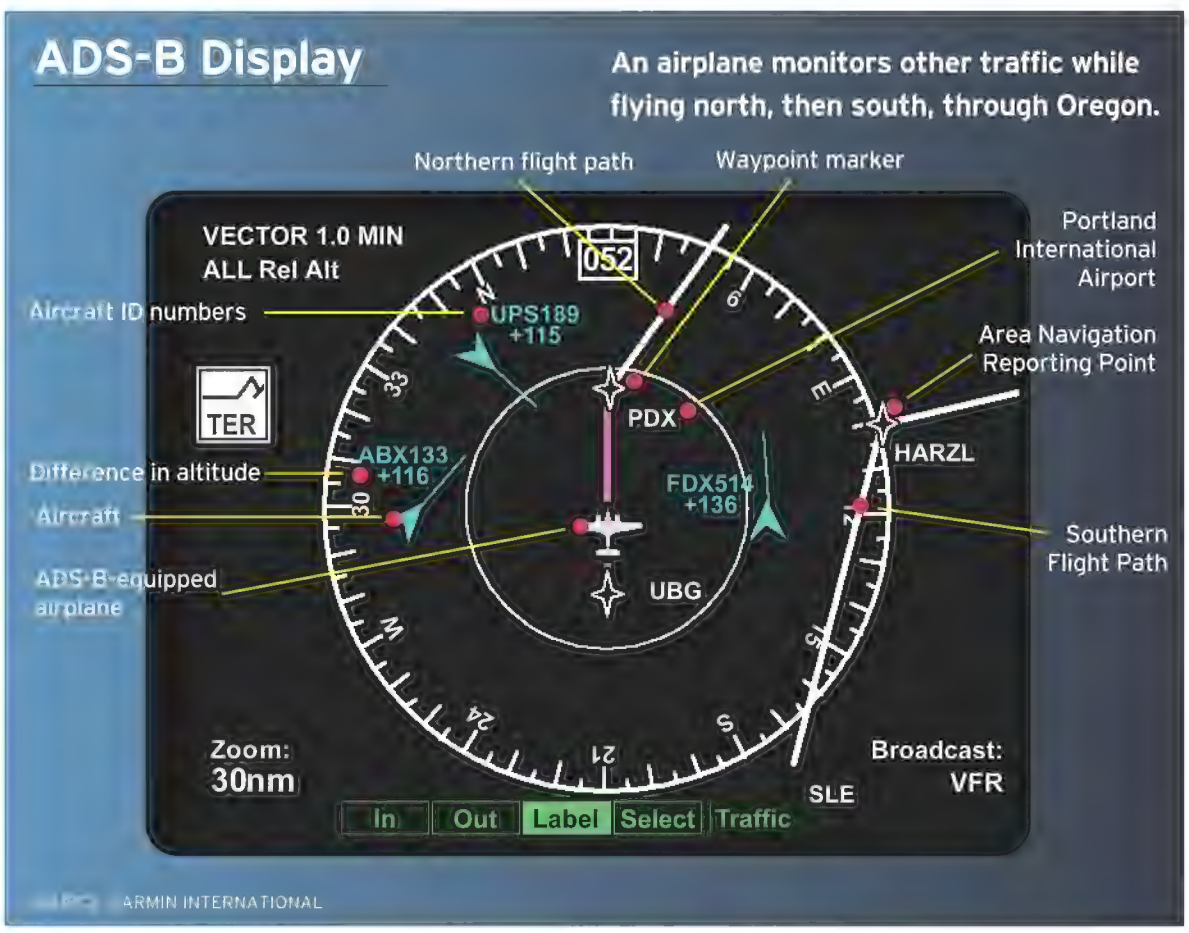
The primary system is enhanced by Secondary Surveillance Radar (SSR). With each radar sweep, a second, high-frequency signal is transmitted along with the primary. When an aircraft equipped with a transponder receives that signal, the transponder sends out a signal of its own, which registers at the ground station.

The SSR uses that return signal to determine aircraft location much more accurately than the primary system could alone, and it eliminates radar returns from spurious sources, such as birds and terrain. Responses from a Mode A transponder include a four-digit identification code assigned by a ground controller via radio, which pilots update manually during flight. Mode C transponders also transmit altitude information, obtained from the aircraft's barometric altimeter.

An improved surveillance radar technology is Mode S, for Mode Select. Each Mode S-equipped aircraft has a unique, permanent identification number that remains during the life of the aircraft. It enables the air traffic control computer to tailor its interrogations, addressing only specified targets.

Once an air traffic control computer identifies an aircraft by its address, that aircraft goes into a "roll call." Subsequent interrogations are transmitted on a schedule. As a result, to track a target, Mode S needs far fewer interrogations than earlier radars, which translates into more accurate position reporting.

A Mode S transponder doesn't have to wait until it's prompted from the ground



entification

to send out its address. It does so continually, and the unsolicited signals, or "squitters," can also include readings from the aircraft's altimeter, plus other flight information. This capability enables new kinds of air-to-air communication, such as the automatic signals of TCAS, the Traffic Alert and Collision Avoidance System, which helps prevent midair collisions.

ADS-B goes further. At least once per second, the aircraft broadcasts not just ID and altitude but also the other essentials of target tracking, azimuth and range—all without interrogation from the ground.

It does this via an "extended squitter," using a signal that is longer than most Mode S signals. With the extended squitter, the aircraft can downlink flight details such as airspeed, climb or descent rate, and magnetic heading. Other aircraft and ground stations within about 150 miles receive the information in their cockpits or consoles.

An ADS-B-equipped aircraft includes a Cockpit Display of Traffic Information, showing the pilot a view of neighboring traffic similar to what the controller sees on the ground. Other information is uplinked from the ground, including positions of nearby aircraft not equipped with ADS-B, weather data, and other updates.

Installing ADS-B will usually involve modifying the Flight Management System software and making new hard-wire connections between the FMS and the transponder.

Instead of using extended-squitter transponders broadcasting at 1090 MHz, general aviation aircraft will be equipped with simpler "universal access transceivers," which broadcast at 978 MHz.

The transceivers will also be installed on airport ground vehicles, because ADS-B functions on the ground as well as in the air.

The development of ADS-B is continuing, with implementation coming in stages over the next decade and beyond as radars gradually are decommissioned. For older aircraft, the cost of conversion to ADS-B would be prohibitive.

So in the meantime, aircraft that do convert will be equipped with a hybrid technology, capable of handling both the old system and the new.

"If they're interrogated, they will reply to that interrogation, but they'll also spontaneously broadcast their information," says Vincent Capezzuto, the FAA's ADS-B program manager.

One of the issues facing the FAA and its project partners is security. The new system depends on air-to-ground and air-to-air broadcast. In a pure ADS-B environment, an intruder who disables the broadcast capability could essentially become invisible. What's needed is "some backup surveillance system that would find you even if you don't want to be found," says Basil Barimo, vice president of operations and safety at the Air Transport Association. That may require retaining at least some primary radars.

The brass ring in developing ADS-B and related services is a national airspace system that can handle more aircraft.

That probably means an air network that doesn't depend on radar. Unlike radar, ADS-B's accuracy does not degrade with distance, so airplanes can fly closer without sacrificing safety.

The FAA plans to make the ADS-B system mandatory for general aviation and transport airplanes by 2014.

Global Positioning System satellites provide locations while ADS-B-equipped aircraft share flight information. Communications satellites (not shown) can link air traffic control stations.

THE GREAT

PHOTOGRAPHS BY PHILIP MAKANNA

Phil Makanna has more than three decades of experience photographing old aircraft. His impeccably composed portraits of vintage warplanes have made his "Ghosts" books and calendars the gold standard of aviation Christmas gifts. But Makanna has always focused on the aircraft of World War II. Then in 2000 he met the Aeroplane Collection.

The privately owned Aeroplane Collection is dedicated to restoring and preserving engines and aircraft from World War I. The collection currently owns 21 craft, both vintage and reproductions. Based in Paso Robles, California, it is also an easy trip from Makanna's San Francisco home.

Above: Makanna's book starts with a classic World War I fighter, the British Sopwith Camel. Right: Debuting in 1915, the petite French Nieuport 11 fighter was based on the design of several pre-war racers.

Makanna began photographing the aircraft, eventually making 31 visits to the collection. He watched as four "small piles of lumber" slowly became aircraft that left the ground powered by engines nearly 90 years old. All told, he spent five years making portraits of the fleet. The result is the book *Ghosts of the Great War: Aviation in World War One* (Ghosts, 2005). Makanna's color portraits are complemented throughout by black-and-white archival images of the same aircraft types.

Helping Makanna get the air-to-air shots was Aeroplane Collection principal Javier Arango, who flew most of the camera plane missions and many of the warplanes. Arango also wrote the book's introduction. In it, he notes that in 1914, when the Great War began, the world had very few airplanes: France, only 250; Germany, 300. But with the conflict in the trenches stalling out, strategists turned to aviation, and designers responded quickly. Fokker, for example, designed and built more than 60 prototypes during the war. "Almost every conceivable aerial variation was tried," writes Arango, "from monoplanes to aircraft with five wings."

By the end of the war, in 1918, France had produced 52,000 aircraft, Germany, 48,000, and Britain, 43,000. The numbers make it clear: The aircraft of World War I are "technological artifacts resulting from serial production," says Arango. But Makanna's photographs show that the old beauties also "still belong to an age of craftsmanship, exquisite details and individual pilots."

>> THE EDITORS

Color photographs reprinted with permission from Philip Makanna.

WARPLANES

PORTRAITS OF MILITARY AVIATION'S FIRST FLEET.

Pfalz D.III »

This German fighter (above) emerged during the reign of the Albatros designs. The wings had U-shaped double spars, instead of the Albatros D.III's weaker single-spar design, which tended to fail. (The Aeroplane Collection's Pfalz is a reproduction, built in the 1960s for the movie *The Blue Max*.)

Fokker hangar »

Master aircraft designer-builder Anthony Fokker got a modest start, assembling monoplanes at this building in Johannisthal, near Berlin, before the war broke out.

Fokker M 5L »

The 1914 rollout of this scout prototype provided a playful opportunity for test pilot Franz Kuntner (third from right), chief pilot Bernhard de Waal (sixth from left), and others at Germany's Görries field.

THE COLLECTION OF PETER GROSZ (2)

Rang du Fliers Aerodrome

At this French field in July 1918, officers watch the skies with binoculars and a telescope on a neck-sparing mount. The tail in the background belongs to a de Havilland DH 9, an early strategic bomber.

THE COLLECTION OF THE IMPERIAL WAR MUSEUM, LONDON

THE COLLECTION OF THEE MUSEE DE L'AIR ET DE L'ESPACE, PARIS

Sopwith Strutter

The circumstances of this sorry scene are lost to history, though the lack of unit markings on the fuselage suggest that this Strutter, a French-built example, was doing service as a trainer. Strutters entered service in 1916 and eventually served as fighters, reconnaissance craft, and bombers, among other roles.

Nieuport 17

When completed, the collection's reproduction of the French fighter will be powered by a 110-horsepower Le Rhône engine and covered in fabric painted in the colors of World War I ace Georges Guynemer.

THE COLLECTION OF AEROPLANE MONTHLY, LONDON

Ship Strutter

>> Used by the Royal Navy to hunt for submarines, this Strutter variant became one of the first aircraft to operate from ships.

Fokker E.III Eindecker

>> Based on a French Morane racer, the Eindecker fighter had sufficient speed, maneuverability, and rate of climb to attack reconnaissance airplanes deftly. Anthony Fokker designed a synchronization gear that timed the firing of the Eindecker's machine gun so that the bullets would not hit the propeller blades.

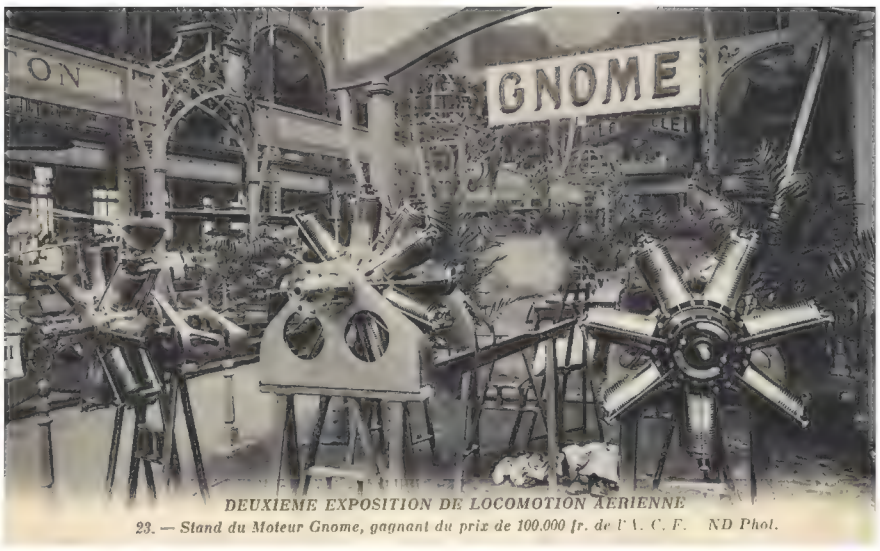
THE COLLECTION OF AEROPLANE MONTHLY, LONDON

Blériot XI >> In 1909, Louis Blériot and his XI made the first aerial crossing of the English Channel. The French design entered the war as a reconnaissance craft, carrying an observer armed with a machine gun. (The collection's example, below, is a reproduction.)

Sopwith Baby >> The Baby was a descendant of the Sopwith Tabloid, a design that won the 1914 Schneider Trophy for floatplanes. Ship-based Babys were intended to take down German Zeppelins, but performance proved disappointing.

Power Source »

The French company Gnome, after buying out competitor Le Rhône, made or licensed the manufacture of 100,000 aircraft engines in World War I.



DEUXIEME EXPOSITION DE LOCOMOTION AERIENNE
23. — Stand du Moteur Gnome, gagnant du prix de 100.000 fr. de l'A. C. F. ND Phot.

THE COLLECTION OF THEE MUSEE DE L'AIR ET DE L'ESPACE, PARIS

THE COLLECTION OF THE IMPERIAL WAR MUSEUM, LONDON

Sopwith Showoff »

Nicholas I, king of Montenegro, visits Royal Flying Corps headquarters in Fienvillers, France, in 1916. A snappy 70 Squadron Strutter awaits his inspection.

SPACE

DID THE FIRST PAYING GUESTS ABOARD THE

Just minutes before it was all over, pioneering space tourist Greg Olsen heard the most memorable two words of his two-year, $20 million odyssey to the International Space Station.

"Olsen," barked Sergei Krikalev, the commander of the Soyuz capsule hurtling back to Earth after the entrepreneur's eight-day stay aboard the ISS, "Kislorod!"

Olsen, the oxygen!

A leak in the reentry capsule was causing a loss of pressure, and with three crew members jammed into the vehicle knee to knee, neither Krikalev nor NASA's John Phillips could reach the oxygen valve that might have to save their lives. In a flash, Olsen appreciated the value of seven months of methodical training at Star City, outside Moscow, with Russian air force instructors repeatedly drilling him to respond to every conceivable emergency.

In this case, the leak was minor and his action at the valve was not critical. But the experience cemented Olsen's belief that he was not merely a tourist, but a crew member.

"That's where the training comes in," Olsen recalls. "I could just tell by watching Krikalev that he had everything under control, and his control gave me confidence."

Dennis Tito, the first paying customer to spend a week in space, spun the 2001 experience in a few guarded interviews as a heavenly idyll from which he was loath to return. (He declined requests for an interview for this article.) Olsen, who became the third space tourist in 2005, and Mark Shuttleworth, who preceded him by three years, are more open and recently described their experiences in unprecedented detail: from cosmic

NASA

BY CRAIG MELLOW

epiphanies to constipation, from awe at the spectacle of Earth from orbit to frustration at the red tape they had to endure to get there.

Olsen and Shuttleworth both struck it rich in high-tech during the 1990s. Olsen founded and sold Sensors Unlimited, Inc., a maker of fiber-optic devices. Shuttleworth created Thawte Consulting, Inc., a designer of Internet security software that he sold to VeriSign, Inc. Aside from that, they have little in common.

Shuttleworth, a South African now based in London, was under 30 when he flew—a bachelor who brought his parents to share the preflight week at Russia's venerable Baikonur launch site in Kazakhstan. Olsen, who lives in Princeton, New Jersey, is a quarter-century older, a divorced father of two grown daughters.

Olsen, who has a down-to-earth personality, recalls that his "Eureka!" moment—deciding to go on a spaceflight—came over his regular morning coffee at Starbucks, reading about Shuttleworth's mission in the *New York Times*.

The first three paying astronauts (left to right, Greg Olsen, Mark Shuttleworth, and Dennis Tito) found that comfort was not guaranteed with their tickets. Enduring the rigors of spaceflight that professonals do was yet another price to pay.

Olsen still compares himself negatively to his spacefaring crewmates, especially "renaissance intellectual" Krikalev. "The only thing I've figured out how to do is make money," he says by way of comparison.

The 33-year-old Shuttleworth has a more remote demeanor, yet comes off as being suffused with romantic enthusiasm. "By 1999, I was in a position where I could do anything, so I asked myself: What is the one thing you want to do before you die?" he recalls during a conversation at a Novotel hotel in London's Docklands. "The answer that came back immediately was to go into space, taking a step down an inevitable path that we as a species have to follow."

He brought a business team to Moscow with him to negotiate each detail of his mission, sometimes dealing across the table from 15 Russian agencies and institutes. Shuttleworth pushed for his own experiments, which he chose from a competition among South African universities.

Olsen also became involved with experiments. When the U.S. military banned him from taking one of his own company's infrared cameras to space for experiments, he gamely agreed to serve as a human guinea pig for a European Space Agency study, making

TRIPPERS

INTERNATIONAL SPACE STATION GET THEIR $20 MILLION WORTH?

OLEG NIKISHIN/GETTY IMAGES

Shuttleworth catches up with his father, Rick, after touchdown.

various abrupt movements while in orbit to see which ones would induce him to vomit. Fortunately, he turned out to be among the (completely unpredictable) 50 percent of travelers who prove resistant to space nausea.

The two tourists also pursued more personal interests. Olsen took lessons from Krikalev on how to photograph his neighborhood in Princeton from space. Shuttleworth arranged to receive a daily bulletin from NASA detailing erupting volcanoes and other extreme geological phenomena he could see from orbit, so that he could knock off work and watch them.

The Generation X-er and the laid-back baby boomer agree on the fundamentals: that their sojourn in outer space was, in the end, worth the money and tribulation. The pair also agree that the trip would not have been worth it just to act the millionaire, paying for a week of thrills. Much, if not most, of the lasting satisfaction for these two high achievers came from meeting the challenges of learning the Soyuz and ISS and living among the global astronaut/cosmonaut elite; training with space masters for four hours a day and winning their respect. "The high point for me was just completing the task," Olsen recalls. "After I landed, the first thought that came to me was, 'Thank God I didn't screw up.' "

Both Olsen and Shuttleworth also learned afresh that neither money nor technology can protect you from unforeseen difficulties or insulate you from unexpected joys. Serendipitous salvation came to Shuttleworth before his launch, as he contemplated whether he really wanted to go through with being "an ant inside a cannonball, where the behavior of both the cannon and the ball are entirely out of your hands."

At that moment of indecision, his cell phone rang: it was a wrong number from South Africa. This injection of absurdity somehow gave him the courage to board the Soyuz. "That guy had no idea what was going on," he laughs. "But it was a great morale lifter."

Olsen came nearest to despair when his outgoing Soyuz arrived at the space station. After two cramped days and 35 orbits aligning the capsule's trajectory so it could dock with the ISS at 17,000 mph, the exit door refused to open. Olsen and his chaperones on the flight up, Bill McArthur and Valery Tokarev, set to good old-fashioned pulling, wedging their feet against the Soyuz floor as best they could for leverage. Visions danced in Olsen's head of a summary return to Earth, with an uncertain prospect of any refund on his $20 million.

But after five minutes the jam inexplicably gave way. The three fliers entered the station at last, to find Krikalev and Phillips floating forward to extend a modified version of the traditional Russian welcome of bread and salt. "You can't use real salt because it would fly around everywhere," Olsen recalls, "so they have bread and put a water–and–salt solution on it." The moment was no less delicious.

THE GIG AS a space tourist starts with a vision, a considerable net worth, a big chunk of free time, and a reasonably but not obsessively fit body (being slightly overweight is an advantage when dealing with weightlessness.)

But it also starts with a mountain of paperwork. Escaping Earth's gravity first requires attaining enough velocity to plow through the bureaucracy of the Russian government.

Shuttleworth's image looms, and Tito lurks, at a Space Adventures press conference.

Waiting Their Turns

Despite the cost and hardship, some of the world's wealthiest people are eager to try their hands at space travel.

The fourth paying space tourist was to have been Japanese businessman Daisuke Enomoto, 35. The former executive of Web tech powerhouse Livedoor spent months training in Star City, Russia, for a 10-day September excursion to the space station, but in the last two days of training, Russian officials announced he was unable to fly due to an unspecified medical condition. Enomoto may have another chance on future missions if later medical tests clear him.

Set to take Enomoto's place at press time was Anousheh Ansari, 39, an Iranian-born naturalized U.S. citizen who trained as his backup. Ansari, who with her brother co-sponsored the X Prize competition for the first commercial manned spaceflight, is known to the Russians and to space tourism broker Space Adventures. In February, Space Adventures contracted with the Ansari family's private investment company to develop suborbital vehicles for commercial use; the fleet will be built in conjunction with the Russian Space Agency.

The newest hopeful eyeing a trip to the station is Charles Simonyi, 59, formerly of Microsoft, who passed a slate of medical reviews in August. The Hungarian-born American, listed as the 746th richest person in the world by *Forbes* magazine, was a developer of Microsoft's Word and Excel applications.

"People always ask me whether I was scared going into space. I answer them, 'Yes, I was scared I wouldn't get to go.' "

–GREG OLSEN

STRINGER/AFP/GETTY IMAGES

Olsen waves the Stars and Stripes while floating in a zero-gravity simulator on board a Russian Il-76 aircraft. Within two months, he was vacationing aboard the International Space Station.

As the first to fly, Dennis Tito battled 10 years for his chance, including outflanking fierce opposition from NASA by booking with the Russian Space Agency. Shuttleworth was able to compress that to less than two, but only through a lobbying campaign in Moscow that spared neither resources nor time.

"There are the guys who make the vehicle, the guys who do the training, the guys who give the medical certification, and you have to contract with all of them separately," he says, describing the hellish talks that preceded his flight.

The software superstar decided to "convince the Russians I was really serious by doing the horrible stuff first." That meant checking in for "three weeks of pretty comprehensive poking and prodding" at Moscow's Institute of Medical and Biological Problems. The date was late 2001, and the cosmonauts' hospital bore the earmarks of a decade of post-Soviet shortages and neglect: "It was quite extraordinary to be tested by the same doctors and on the same equipment as all the early cosmonauts," Shuttleworth says.

Olsen, who made his first trip to Russia in October 2003 and flew in October 2005, reported no particular business hassles, relying on the Tito/Shuttleworth precedent and his own go-with-the-flow attitude. "I paid up, showed up, and shut up," he summarizes.

Nonetheless, his mission was almost derailed when, in April 2004, doctors found a spot on one of his chest X-rays. It took nine months of affidavits from U.S. physicians to persuade the Russians it was harmless. "People always ask me whether I was scared going into space," Olsen says. "I answer them, 'Yes, I was scared I wouldn't get to go.' "

While Olsen relied mostly on translators at Star City, the fabled compound in the pines that has incubated Russian space pioneers since the days of Yuri Gagarin, Shuttleworth plunged into four hours a day of Russian language tutoring. He considered this "like brain surgery without anesthetic," but essential to the experience.

Shuttleworth's struggles to cope with Russians and Russian-ness continued during his cosmonaut training. But they shifted from a bureaucratic plane to an emotional one, and became far more rewarding.

"Living in Star City for eight months shapes you perhaps more than the act of flying in space," he reflects. "To be immersed in a culture that is fascinating, complex, difficult, and where you are at once welcome and excluded."

He remembers the cradle of Soviet spaceflight as a cross between "an isolated village in the forest with its own sauna" and a throwback to the university days he had completed in Capetown just six years earlier: "It's a lot like school. You crisscross campus all day from the simulator to the hydro lab. There are standard, pre-packaged chunks of knowledge you have to absorb in order to graduate."

"Being willing to sit in the cosmonauts' quarters and celebrate someone's birthday with rounds and rounds of vodka brings you closer to the group."

–MARK SHUTTLEWORTH

STEPHEN CHERNIN/GETTY IMAGES

NASA

"Spaceflight participant" Olsen (center) poses with the pros.

Classes are interspersed with two hours of physical training a day. But Star City is no boot camp. "The folks at one of the universities back home were pushing me to get in terrific shape for one of the experiments I'd be performing," Shuttleworth recalls. "The Russians were more worried that I'd turn an ankle if I was running too hard."

As at college, no one lets the course work get in the way of long nights of socializing. Shuttleworth and Olsen lived in a dorm reserved for foreigners; their neighbors down the hall were astronauts from Italy and Brazil. But the young South African's overriding social goal was to pledge the fraternity of Russian space jocks across the quad, and that meant participating in their time-honored rituals.

"Being willing to sit in the cosmonauts' quarters and celebrate someone's birthday with rounds and rounds of vodka toasts brings you closer to the group," he says. "And they're very gracious afterwards. They'll walk you home and make sure you don't die falling into a snow drift."

Olsen was content to keep his distance from the epicenter of Star City partying. His best friend in the compound became American astronaut Bill McArthur, and the two wiled away the country nights in a gentler manner than their Russian colleagues: "Bill and I just hit it off. We found out we both enjoyed red wine. We both have two daughters. We had a lot in common."

Olsen's training memories focus more on the mission prep itself. He wowed his handlers early on with his extraordinary balance: "The Russians have this dentist's chair, and as you're spinning in it, you make head movements. They believe you can get used to it and prepare yourself for weightlessness, while NASA doesn't subscribe to that at all. What I can say is I did religiously everything the Russians told me to do and I didn't get sick."

But Olsen still burns with chagrin when he recalls small screw-ups, like tangling his seat belts the first time he rehearsed routines inside the Soyuz capsule. "Olsen," snapped cosmonaut Valery Tokarev. "Belts twisted." After that, the multimillionaire guest flier snuck into the Soyuz on his lunch hour, snapping and unsnapping his three sets of restraints until he could do it in his sleep.

There was pressure to live up to the skills and aptitudes of the men who spend half a year at a time in a 150-foot tube hurtling through space.

"Two things equally surprised me about the astronauts and cosmonauts," Olsen says. "One is how super-competent they really are. The second is that there is none of the superstar-ism that you see in athletics. They are typical of the best aspects of military culture. They are mission-oriented, not self-oriented."

INTENSE AS STAR CITY may be, it doesn't take long to leave it, and the rest of the planet, emotionally behind once the Soyuz roars into space. As Greg Olsen remembers it, it took about four minutes.

By then the rocket has climbed to 50 miles. It casts off its protective heat shield and "you look back and see this big blue sphere slowly receding from you. I had such a feeling of joy and peace."

Aboard the ISS itself, Olsen was struck by the fast pace and regimentation of the day. His astronaut/cosmonaut friends had traded carousing in the Russian woods for a life of endless drills, punctuated only by half a dozen daily briefings in which mission control assigns more drills. "There is a procedure for everything in space," Olsen relates. "The astronauts don't have all that much free time between experiments, all the maintenance work they have to do, and conferences with the ground."

Shuttleworth was impressed by the odd aesthetics of a facility that seems to have borrowed interior details from its doomed predecessor, Mir. "The space station is sort of super high-tech and super low-tech at the same time," he notes. "A lot of the design features look like a 1960s or '70s caravan [trailer]."

Olsen's recollections are more visceral. One of the lesser-known effects of weightlessness, he relates, is that it slows your digestion. On his sixth day in space, NASA doctor Richard Jennings asked Olsen, during their daily private medical conference, whether he had moved his bowels yet. The space visitor said that he had not. "Don't worry, Olsen, you'll never break the record," Jennings answered. "It's 14 days."

Characteristically, the young

South African focused on the interpersonal subtleties of five men sharing limited room in outer space. "It's a bit like coming to someone's house, because there's a team that has already been up there for six months," Shuttleworth says. "Coming to work with them in their house under stressful conditions."

Their interludes aboard ISS took place during eight-day shift changes, with two pairs of astronauts plus themselves cohabiting. The two tourists had the luxury of four hours a day of free time, while the professional astronauts were busy with the orbital equivalent of swabbing the deck.

Both visitors spent a lot of time watching the world go 'round beneath them. "Just floating and looking out the window.... Those are great memories," Olsen says.

Shuttleworth drew moral conclusions from the vista: "It's amazing to see how connected the Earth is. It takes 23 minutes to cross Africa from Morocco to Mozambique. It makes you feel we have to be a lot more cautious about how we use it."

> "By 1999, I was in a position where I could do anything, so I asked myself: What is the one thing you want to do before you die?"
>
> –MARK SHUTTLEWORTH

And after it was all over? Both space tourists alighted on terra firma unemployed but mildly famous: "It's hard to say whether it's the experience that changes you or the way people treat you afterward," Shuttleworth observes.

They both say they would go up again, though not to repeat the same mission. The pair naturally turned to proselytizing for space and science education. Shuttleworth pursued this mission with more fervor and single-mindedness, touring schools and addressing as many as 1,000 students at a time.

He made a name for himself as "the first African in space," but also gained "a real appreciation of the downside of the rock star's life."

Burn-out happily brought Shuttleworth back to his first love, software, and he is currently absorbed in gestating Ubuntu, a Linux-based operating system.

"I'd love to fly again, but I think I've stretched the Russian Space Agency for everything it has to offer," he says.

Greg Olsen has visited more than 150 U.S. schools and colleges in the year since his ISS mission. But the pace still leaves him plenty of time to commune with his coffee and newspaper at the Starbucks on Nassau Street, or stare out the window at the university campus "figuring out what to do with the rest of my life."

In the meantime, the nascent space tourism industry Shuttleworth and Olsen helped kickstart is moving forward—at least for those with tens of millions in disposable income.

And the $20 million price tag is not likely to drop any time soon, according to Space Adventures, the Virginia-based company that acts as a travel agent for these trips. Company spokeswoman Stacey Tearne says that the price, determined primarily by the Russian Space Agency, will more than likely increase as more people sign up to go (see "Waiting Their Turns," p. 48).

Space is not yet open to the ocean cruise crowd, which is why people like Olsen and Shuttleworth chose to go. When reaching orbit is considered cheap and easy, look for over-achievers like them to be camping on Mars.

NASA

Shuttleworth prepares for his turn in orbit at a Russian Space Agency facility. The agency is using tourist dollars for survival.

NEWSMAKERS/GETTY IMAGES

Tito is dwarfed by cosmonauts while at Star City. It took a decade for him to reach orbit, over NASA's objections.

The Next Little Thing

Why 2006 is the year of the very light jet.

by Mark Huber

AMERICAN HONDA MOTOR CO.

AT THE WORLD'S LARGEST gathering of propeller-driven airplanes, this year's big news was jets. A whole new class of jet aircraft, very light jets, dominated the general aviation exhibits at the Experimental Aircraft Association's Oshkosh, Wisconsin airshow. No fewer than seven companies—Adam, ATG, Cessna, Diamond, Eclipse, Embraer, and Honda—had little jets, or mock-ups of them, on display, and there was buzz at every booth.

As a class, VLJs incorporate significant advances in airframe design, engines, computerized avionics, manufacturing techniques, and materials. The advances, developed mainly over the last decade, make these small aircraft easier to operate than jets of the previous generation and—even with jet fuel now hovering around $4 a gallon—more affordable to fly. The new class consumes half the fuel that older corporate jets do, so many more pilots can afford to own jets today than could a decade ago. The Federal Aviation Administration predicts that 4,500 light jets will be flying by 2016. (To put the potential impact of VLJs in perspective, consider this: There are 15,000 business jets currently operating worldwide, and Cessna, the most prolific manufacturer of them, plans to deliver 290 this year.) When FAA Administrator Marion Blakey awarded the Eclipse Model 500 provisional certification at Oshkosh last July—timing that contributed to the fanfare—she said, "This is a real game-changer for our industry."

The rules of that game actually began changing as early as 1970, when Cessna introduced the Citation, a "slow" 400-mph jet that made it possible for pilots who had been flying 300-mph twin turboprops, like the popular Beech King Air, to step up. Transitioning to a 100-mph-faster airplane that could fly about 10,000 feet higher than the airplanes private pilots were accustomed to wouldn't demand as much training (or money) as would be required to fly the 500-mph jets with 40,000-foot ceilings that populated the inventory at the time (see "Getting Up to Speed," p. 56). Within a decade, the Citation stole much of the twin turboprop market. Today, Cessna Citations account for one-third of all new business jet sales. (Cessna has also jumped into the very light jet market with its six-seat, 390-mph Citation Mustang, which is on track for certification later this year, but CEO Jack Pelton resists calling it a VLJ; rather, he labels it a "downward expansion of the product line.") The Citation brought more pilots into the jet fold. Enticing even more would mean finding the next niche: a jet even cheaper and easier to operate than the Citation.

What's a VLJ?

A jet aircraft...

- weighing less than 10,000 pounds
- seating four to nine passengers
- with a cruise speed of around 400 mph
- a range of 1,100 to 2,300 miles
- and the ability to take off from runways shorter than 3,500 feet.

Honda's in! As announcements go, this was a whopper. More than 15 years of development preceded Honda's decision, trumpeted at this year's Oshkosh, Wisconsin fly-in, to build the HondaJet. Most attentive listeners? Other jet builders.

Engines First

While the Citation was causing a small upheaval in business aviation, engine maker Sam Williams was working on small turbofans, the least fuel-hungry type of jet engine operating today, to power cruise missiles. Williams believed the little engines might create the next general aviation niche. "He always thought anyone who could fly would prefer to fly a jet," says Matt Huff, vice president of business development for Williams International. Huff says that the turbofan technology developed for cruise missiles did not directly carry over to the family of powerplants Williams eventually designed for today's VLJs, but adds, "We did learn an awful lot of lessons from the cruise missile program that helped us when we decided to go into general aviation."

An interim step was the 2,300-

COURTESY SPECTRUM

AMERICAN HONDA MOTOR CO.

Loveliest of light jets, the Spectrum Model 33 weighs under 4,000 pounds empty. The sole prototype crashed last July. Left: Like others in its class, HondaJet features cockpit displays that integrate navigation and systems data.

pound-thrust FJ-44 turbofan. The engine entered commercial service in 1993 and to date Williams has produced 2,400.

But Williams believed the real production increases would come when a significant percentage of private pilots flying piston-powered twin-engine aircraft (18,469 airplanes in the United States, according to the FAA) could transition into a new category of light jets. In 1996, the company partnered with NASA's General Aviation Propulsion Program. Conducted by the Glenn Research Center in Ohio, the program was one of several NASA-sponsored efforts to revitalize the sagging U.S. general aviation industry. Williams said in a company press release the following year: "Our objective is to replace aging, piston-powered light aircraft with all new, four-place single and six-place twin, turbofan-powered modern aircraft. This means we must develop a turbofan in the 700-pound thrust category that is very low in cost at a high production rate, is extremely quiet, is light in weight, and is very reliable."

General aviation's best friend, NASA's Bruce Holmes, told Bob Simon on *60 Minutes* last year that air travelers would soon be able "to hail a jet cab."

Williams had hired Burt Rutan to build a demonstration aircraft, the V-JET II, to showcase his new engine. The V-JET, looking the part of the revolutionary, made its first public flight at Oshkosh in 1997. Built of composite materials, the aircraft had a V tail, a nose shaped like a fighter's, forward-swept, drooping wings, and a portal windshield. It was extremely quiet thanks to the pair of experimental 550-pound-thrust, low-pressure Williams FJX-1 engines it was built for.

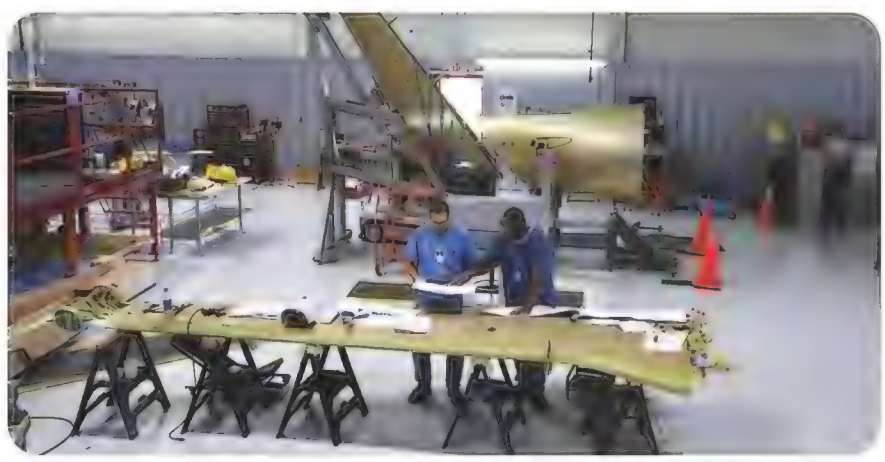
One of the first true believers the V-JET called to the cause was Vern Raburn, today the CEO of Eclipse Aviation. Raburn,

JEFF CAPLAN/NASA

a 7,000-hour jet-rated pilot who had held senior executive positions at Microsoft, Lotus Development, Symantec, and Slate, founded Eclipse in 1998 after several discussions with Sam Williams. The company's original engineering team was for a time housed at Williams' headquarters.

The Eclipse-Williams relationship soured in 2002 after the 700-pound-thrust EJ-22 engine, a descendant of the V-JET's FJX-1, suffered repeated flight test failures (see "The Little Engine That Couldn't," Feb./Mar. 2005). However, by then Williams already had developed an 80-percent-scale version of its FJ-44 corporate jet engine. The new FJ-33 weighs just 300 pounds and delivers 1,000 to 1,500 pounds of thrust. It incorporates advances pioneered on the FJ-44, including scalloped exhaust pipes that reduce engine noise and widely swept and rounded fan blades, which contribute to lower noise and better fuel economy.

To date, the FJ-33 has been selected to power four VLJ designs seeking FAA certification: Adam A700, ATG Javelin, Diamond D-JET, and Spectrum 33.



Look, Ma! Almost no rivets! Eclipse parts are joined by a welding tool that leaves smooth, silvery stripes. Rivets are used to attach brackets inside the fuselage and wing ribs to the spar (left).

The Other Little Turbofans

Eclipse began looking for a replacement engine in late 2002, and by then, Pratt & Whitney Canada (PWC) was already far along on the development of its PW600 series of 900- to 1,700-pound thrust engines. In 2003, PWC announced its first order, from Cessna, for the 1,350-pound-thrust PW615F, weighing 300 pounds.

The new engines incorporate a host of proprietary technologies including unique fan blade shapes and a high-efficiency compressor, which produces a pressure ratio in two stages that other engines need three or more stages to achieve. PWC also invented a modular construction technique that enables the engine to be assembled faster and serviced easier. For both private pilots and jet taxi businesses, less expensive and faster engine servicing will be an important sales advantage. Modular construction and a new assembly facility in Longueuil, Quebec, helped the company slash the average engine's production, test, and shipping time from eight days to a mere eight hours. The plant is gearing up to produce as many as 2,000 engines per year.

To date, PWC has contracts to supply engines for Cessna, Embraer, and Eclipse.

And then there's Honda. GE Honda Aero Engines, located in Cincinnati, Ohio, was formed two years ago to improve Honda's HF118. With 1,700 pounds of thrust, the little turbofan is competitive with the PWC and Williams engines, but so far the HF118 will power only the HondaJet.

Geek Spoken Here

The infusion of oddball ideas or unconventional practices may not produce immediate business success, but it can stir other businesses in an industry to innovate. In the case of VLJs and the aviation industry, the new ideas have come mainly from the computer business.

Several leaders of the very light jet revolution come from the computer or software industries and have brought with them some principles of software development that challenge the aviation industry's evolutionary tradition. "In the high-tech business, the non-existence of a market and a product for it is viewed as an opportunity," says Vern Raburn. "It's like, 'Cool, no competition.' In aviation, the non-existence of a market or product is used to say it can't exist or it shouldn't exist. Remember the old Bob Dylan lyric, 'One man's ceiling is another man's floor'? Well, that is how I could characterize aviation."

Raburn's biggest customer for the Eclipse 500 is Ed Iacobucci, who worked at IBM, then founded Citrix Systems, retired, moved to Florida, and invented DayJet, an air taxi company that depends on "complexity science" for scheduling. Developing the computer models to give customers the flexibility of a taxi service is an undertaking on the order of the manned moon missions, but with the help of the Georgia Institute of Technology and the Santa Fe Institute, Iacobucci has created the system that will make it work.

Raburn has suffered slings from market analysts, who have referred to Eclipse as a "dot.com with wings," but if he can hold his price—a new Eclipse ordered

today would cost $1.6 million—he will be selling a five-seat, twin-engine jet for the same price pilots now pay for a single-engine turboprop with as many as 12 seats. The next-cheaper twin VLJ is Adam's A700 (with seven seats instead of five), selling for $2.25 million. To hit his price point, Raburn believes he has to change how an airplane is made.

The surprise: After studying composite construction, he chose aluminum. "Composites can't be scaled," he says, to meet the company's mass production model envisioned at 500 aircraft a year. That's how many Eclipse 500s the company must build (and sell) in order to break even, according to Raburn.

"By the end of next year," says company spokesman Andrew Broom, "we'll be able to build three or four airplanes a day. That's a thousand airplanes a year."

To build airplanes that quickly, Raburn has replaced the manual method of riveting pieces together with an automated aluminum construction pro-

Uniquely shaped fan blades increase efficiency and reduce noise on PW600 engines from Pratt & Whitney Canada. Three very light jet companies have selected the engines.

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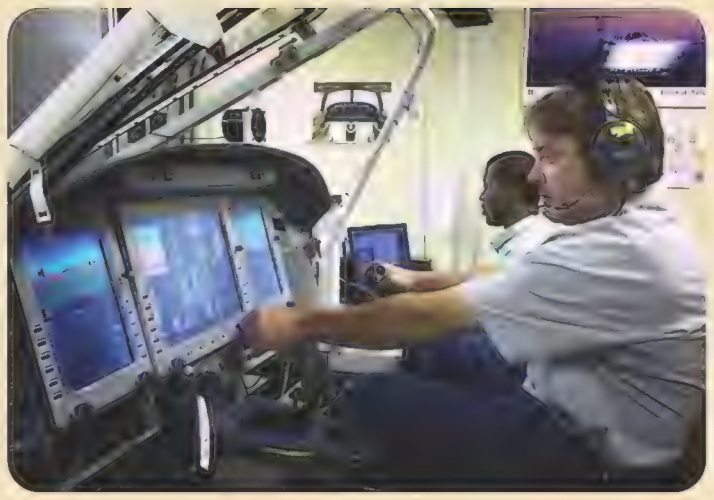
Getting Up to Speed



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Perhaps half of all very light jets will be flown by pilots who have had little or no experience flying at the speeds or altitudes reachable with their new aircraft. (Most VLJs will have service ceilings of 41,000 to 45,000 feet.) The need to make decisions will come quickly in a VLJ.

The dangers in thin air are myriad. There is a smaller spread between cruise and stall speeds, and any kind of upset – clear-air turbulence, for example – can compromise aircraft handling characteristics.

In the early 1960s, several Learjet accidents were attributed to "departures from controlled flight," often beginning between 41,000 and 45,000 feet. Similarly, during the 1980s and 1990s, a few pressurized Piper Malibus broke apart when their pilots encountered thunderstorms or other forms of severe turbulence.

"We understand the early Learjet accidents," says Don Taylor, a retired 31,000-hour United Airlines 747 instructor and now the director of training for Eclipse. "People need to stay ahead of the airplane. Things happen faster at the higher altitudes and it is a hostile environment." Taylor blames most of the early Learjet accidents on insufficient pilot training.

Eclipse Aviation engineers test an "operating system" that will make flying jets easier, but new pilots will still need intensive training.

Eclipse and Adam have designed aggressive screening and training programs to prepare pilots for their first flights to altitudes above 18,000 feet. Cessna will have training giant Flight Safety International provide pilot training.

The National Business Aviation Association has issued "Training Guidelines for Single Pilot Operations of Very Light Jets and Technically Advanced Aircraft," which includes guidelines for the minimum experience, technical training, and mentoring a private pilot should have.

Eclipse has contracted with United Airlines to provide pilot training in its VLJs beginning next year. At United's Denver training center, prospective pilots will undergo a flight skills assessment that will include flying a Boeing 767 simulator. The type rating program itself is initially expected to take eight days, with 12 to 18 hours of flying time.

Adam Aircraft plans to keep its pilot training in-house. "The course is not time-based, it's proficiency-based," say training director David Thompson. It may take you five days or 10 days, but we won't quit until we get to that proficiency level."

Adam is also considering a high-fidelity, no-motion simulator for VLJ training.

cess known as friction-stir welding. The process was first used on rockets, but never tried extensively on aircraft.

Friction-stir welding was invented and patented in 1991 by the Welding Institute in the United Kingdom. Using specialized tooling, a manufacturer first softens without melting two pieces of metal to be joined. A spindle then stirs the two pieces of aluminum together. The plasticized material is transferred from the front of a pin tool to behind it as the tool traverses along the joint. Because the aluminum never melts, friction-stir welding more closely approximates a forging or extrusion process rather than traditional welding.

Eclipse claims that friction-stir welds are two or three times stronger than single-row riveted joints and that the process is 10 times faster than manual riveting, and four times faster than automated riveting. The company says the process will produce very smooth surfaces, thereby further reducing assembly time by cutting the time required to prepare the aircraft for painting.

"We invested about $30 million" to make the welding process applicable to the Eclipse, says Raburn. The company uses custom-made computer numeric control machines that automatically weld the aircraft structure from the inside out, creating an exterior skin just as smooth as composites, says Raburn. "The great and obvious payoff for us is the speed," says Raburn. "We can weld an entire set of airplane parts in one shift in eight hours that replaces 1,700- to 1,900-man hours and multiple shifts to build the airplane."

Another computer whiz bringing software sensibilities to the aviation industry is Adam Aircraft CEO George F. "Rick" Adam. Adam ran the Real-Time Computer Center at the Kennedy Space Center during the Apollo program before taking a string of tech jobs that culminated with the chief information officer slot at finance giant Goldman Sachs. He founded Adam Aircraft in 1998, initially to make new-generation piston aircraft, but in 2003 began development of the $2.25 million A700 very light jet. The company expects to have the A700 certified next year and currently has 310 orders for it.

"I was always struck by how little new technology was making its way into airplanes," says Adam. "If you bought a general aviation airplane, it looked just like it did 40 years ago. That always struck me as really unnatural."

Rick Adam formed his company in 1998, originally to manufacture piston-powered aircraft. He hired Burt Rutan to design an airplane adaptable to either two centerline-thrust piston engines or two turbines. (The piston-powered airplane, the A500, got great product placement in last summer's film *Miami Vice*.) Below: Two halves of an A700's carbon-fiber fuselage were formed and bonded together at Adam's Colorado plant.

COURTESY ADAM AIRCRAFT (2)

Adam has a more modest production plan than Eclipse and still thinks composites are the way to go. Both the A700 and A500 piston aircraft are fashioned from carbon fiber composite, and Adam credits this construction with holding down costs as well as providing a lighter aircraft and a more voluminous cabin. (With composite construction, there is no need for ribs, stringers, or any of the other support structures that hold aluminum fuselages together.)

"It is much less expensive to design and tool an airplane in composites than it is in aluminum," Adam says. "In aluminum, you have to go to a tool-and-die maker, and the typical turnaround is six to nine months." (Raburn figures differently: It's cheaper to tool a composite aircraft, but the material is more expensive than aluminum. Raburn is counting on an automatic production line for further savings.)

"We do all of our own tooling in-house," says Adam, "and we can build a tool in a week. In software, we used to call this 'rapid prototyping.' If we make a mistake, we fix it in a couple of days. If a guy in aluminum tooling makes a mistake, it loops back through months and months and months. Time is money. By cutting down the elapsed time, we use less money."

Adam calls the carbon fiber technology used in his aircraft "second-generation." It is a composite pre-impregnated with resin and supported by sandwiched honeycomb, similar to that used on the Raytheon Premier and Hawker 4000 business jets and what will be used on the Boeing 787 Dreamliner. Adam claims it yields a weight savings of 10 to 15 percent over comparable aluminum aircraft.

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COURTESY DAYJET

Above: The history and future of aviation? A Federal Express 727 whips by for a landing behind DayJet's new little taxi. DayJet founder Ed Iacobucci (at left) has ordered 239 Eclipse 500s from Vern Raburn with an option for 70 more.

A Career with Composites

Not everyone building a very light jet is an aviation outsider. Linden Blue has been a leader in the industry for 30 years, beginning with Gates Learjet in 1977, where he was executive vice president and general manager. He has been a composites champion for most of that time, and especially since his directorship at Raytheon, when he supported the doomed but dazzling Starship twin turboprop (see "Beached Starship," Aug./Sep. 2004). Since 1986, he has served as co-chairman of General Atomics, the company that makes the famous Predator series of unmanned aerial vehicles for the military. The Predator can stay aloft for 40 hours without refueling, thanks in part to its lightweight composite construction. Over the last 20 years, Blue has also been funding composite research, and in 1998 he formed Spectrum Aeronautical to take advantage of the technology.

"I've made so many mistakes," he says, "it was just a matter of evolving the process over 20 years and getting it right."

Spectrum toiled in secret until last fall when the wraps were taken off its 10-seat Model 33 jet. The company, which is run by Blue's son, Austin, claims the 33 will have a range of 2,300 miles and cruise at 477 mph with the same hourly fuel consumption as the much smaller Eclipse. It will also be able to use ridiculously short runways. On its maiden flight from Spanish Fork, Utah (elevation 4,529 feet), last January 7, the 33's reduced-power takeoff roll was just 750 feet, less than one-third of what a Cessna Citation CJ2 would require. (The same prototype crashed on takeoff from that runway last July 25, killing both test pilots. Preliminary investigations indicate that during a maintenance check, the flight control linkages were reconnected incorrectly.)

"After leaving Beech in 1984, I was convinced the Starship was a conceptually good airplane but poorly executed," says Blue. "If you don't automate composites, you lose control of weight and costs, and you can't have a successful airplane. Raytheon was not ready to bite the bullet and do it right."

Spectrum uses an automated method of fabricating carbon fiber called FibeX. It embeds fibers in the carbon material to provide stiffness and support, as opposed to the heavier honeycomb layer traditionally used. The entire fuselage section of the 33 weighs just 300 pounds. With full fuel and passengers, the Spectrum will weigh about 7,300 pounds, about half what a comparably performing aluminum business jet weighs. Before the recent crash of its lone prototype, the company said it would have its aircraft certified by 2008.

Uncle Sam Lends a Hand

It takes optimism and courage—and perhaps the naïveté of an outsider—to create a new product category in an established industry. It also takes a lot of money. Very light jets will debut after almost 10 years and more than $2 billion worth of private and government-funded research and development.

The government funding came primarily through the Advanced General Aviation Transport Experiments (AGATE) program, which brought together some of the finest and most innovative aviation minds from NASA, industry, and the research community. Bruce Holmes, the associate director of NASA's Langley Research Center in Virginia and the driving force behind the agency's general aviation programs, has pushed to create a "highway in the sky," a dream system that would make it as easy to fly an airplane as it is to drive a car. AGATE did not go that far, but it did lead to streamlining certification procedures for composite aircraft, new lightweight and fuel-efficient jet engines, and advanced and far more compact computer-based avionics that give pilots greater situational awareness and integrat-

Photogenic in any landscape, the Adam A700 VLJ is on its way to certification with 300 orders on the books. Is the light jet market big enough for all comers?

ed real-time weather, terrain, and air traffic data. In avionics alone, the advances have been a dramatic improvement over the equipment in $40 million business jets that are just a few years old, claims ATG President Charlie Johnson.

Avidyne Corporation in Lincoln, Massachusetts, is providing flat-screen primary flight displays for ATG, Adam, Eclipse, and Spectrum jets. The display combines navigation data along with airspeed and rates of climb or descent. The integrated cockpit displays are fed by sophisticated electronic sensors, as opposed to old-style mechanical gyroscopes and accelerometers. The displays not only provide better pilot guidance, but also are lighter, cheaper, and easier to install and maintain than traditional "steam gauge" instruments.

"These electronics weigh less primarily because there are so many fewer wires and connectors and switches," says Avidyne CEO Dan Schwinn.

Before founding Avidyne in 1994, Schwinn led a global communications equipment manufacturer to achieve annual sales of $150 million before it was acquired by computer chip maker Intel. Avidyne supplies the systems to piston-engine aircraft makers Cirrus, Columbia, and Piper and to VLJ makers Adam, ATG, and Eclipse.

Integrated flight deck systems have proven immensely popular. Garmin, best known for its Global Positioning System receivers, has followed Avidyne into the market.

For Schwinn, the key to keeping integrated displays affordable is the successful application and integration of technologies developed for non-aviation industries, primarily automobiles.

"The aviation market isn't that big," says Schwinn. "We had to be good at leveraging technology that was originally designed for another use. So our screens are laptop screens. Our Attitude, Heading, and Reference System uses gyros and accelerometers that were built for car stability systems by the tens of millions."

Avidyne relies heavily on an automotive high-speed, safety-critical data communications system, called FlexRay, developed by a consortium that includes automakers BMW, DaimlerChrysler, General Motors, and Ford; automotive component maker Robert Bosch; and Motorola and Phillips Semiconducters. In cars, FlexRay drives an increasingly elaborate system of sensors and actuators that control things like anti-lock brakes and automatic stability controls.

Small, efficient fanjet engines, systems that make the aircraft easier to fly, R&D money from NASA, and a small group of entrepreneurs who didn't know they couldn't build lightweight, cheaper jets have all come together over the past 15 years to create a resurgence in the U.S. general aviation industry. Orders have been placed for more than 3,500 VLJs, with a total market value of more than $5 billion.

About two-thirds of the orders will form the backbone of a hoped-for air taxi market: a network that could offer on-demand and affordable business travel to the nation's 5,000 general aviation airports. The air taxi business is targeting middle managers, a market its proponents claim is ignored or ill-served by the airlines. The other one-third of VLJs will go to private pilots.

These 3,500 orders do not include any government sales. On January 30, 2006, the U.S. Department of Defense issued a Request for Information to all very light jet manufacturers, asking them to submit data on the applicability of their aircraft in a variety of roles, from pilot training to surveillance. The Air Force plans to start flight evaluations at Edwards Air Force Base, in California, by December. Another reason that 2006 is the year of the very light jet.

COURTESY ADAM AIRCRAFT

The not-so-big dig

WITH THE EQUIVALENT POWER OF AN ELECTRIC CAN OPENER, ENGINEERS TRY TO DO MORE THAN SCRATCH THE MARTIAN SURFACE. >>> BY TOM HARPOLE

Idaho's fields of basalt offer the ideal location for experimenting with robotic drills that may one day bore into Mars.

NATIONAL PARK SERVICE

Planetary geologist James Dohm doesn't mean to disparage when he says Idaho Falls is a lot like Mars. A large, gentle man who has spent 19 years at the University of Arizona mapping the red planet, Dohm sees exceptional possibilities in this city of 50,000 people on the west side of the Teton Range.

Idaho Falls straddles the Snake River headwaters a couple hours' drive southwest of Yellowstone Park, where the Rockies smooth out into central Idaho's sage-studded flatlands. But what makes it special, Dohm says, is what lies beneath—a layer of basalt that is similar to much of the crust of Mars. Basalt—a dark-colored, fine-grained igneous rock rich in iron and magnesium—is one of the barriers that planetary scientists will have to penetrate to get beneath the Martian surface. NASA is preparing now for drilling operations to better understand the planet's evolution and perhaps answer one of its biggest mysteries: Did life ever exist there?

"Basalt is one of the hardest rocks on Earth," Dohm says. "If we're going to bore a hole in Mars, we need to get good at drilling into basalt." Doing so with small but sturdy tools that haven't quite been invented is the challenge.

As with the Earth, the surface of Mars is blanketed with regolith—loose sand, dust, rocks, and minerals deposited atop bedrock by meteors and spread by wind and erosion. Add to that eons of solar radiation bombarding the planet and you can be almost certain that no life remains on the surface. The logical step, for Dohm and other scientists, is to drill.

But deciding when, where, and how deep to drill will drive site selection discussions in the Mars exploration community for the next few years, just as such concerns kept Apollo-era scientists busy deciding where on the moon NASA astronauts should land and go prospecting.

On Mars, "there's evidence of internal heat sources," Dohm explains. In theory, that heat could sustain underground life. Data from orbiting spacecraft strongly suggest the presence of both hydrothermal and volcanic-driven heat flowing to the surface. "We are looking at a dynamic planet," he says.

To go after the secrets beneath Mars, scientists can drill either into rock or ice. Drilling in rock may help them understand the geologic record of Mars, while drilling in ice could provide clues into the biological past. Since there won't be astronauts along at first, making the drill autonomous is one of the biggest hurdles NASA faces.

So far, the space agency has had limited experience in extraterrestrial drilling. The Apollo astronauts hammered, raked, scooped, or drilled for the 842 pounds of moonrocks they brought home. The drilling, in particular, was difficult, as Apollo 15 astronauts David Scott and James Irwin, who landed on the moon in July 1971, can attest.

In boring a hole at Hadley Rille, Scott ran into trouble when the battery-powered drill jammed at about 5.5 feet. He gave up trying to wrestle it out of the lunar rock. The next day, he and Irwin manhandled the drill and its core sample out of the hole.

The problem was a key flaw in the drill's design: Its threads were not carrying the cuttings to the surface. Instead, the cuttings were getting clogged in the hole, binding the drill stem. (Nevertheless, later X-ray analysis of the core showed 58 separate layers of regolith along with various pebbles and an increasing density down to the bottom of the core.) NASA fixed the problem on later flights. On Apollo 16, Charlie Duke drilled to the full eight feet in about one minute. On Apollo 17, Gene Cernan did it in just under three.

Robotic spacecraft also have used drills. The Soviets put drills on their Luna soil-sample return probe to the moon (capable of penetrating about 13 inches) and Venera spacecraft to Venus (just over an inch) in the 1960s and 1970s. The European Rosetta mission, which launched in 2004, is designed to land on a comet in 2014, drill down about eight inches and analyze the contents.

The requirements for a Mars drill are daunting.

The machine must collect cuttings and cores, analyze the samples, and transmit the findings to Earth. It must weigh less than 90 pounds and run on an energy budget of less than 100 watts, drilling a roughly two-inch diameter hole to produce a one-inch core.

Earthbound miners, when boring a two-inch diameter hole for blasting basalt, commonly use 2,400-pound compressors that drive 55-pound drills. Even that is a relatively small outfit compared to the drills used for water or oil wells. No one has ever drilled autonomously on Earth; the rigs require constant human input, and they rely on brute force and extreme horsepower to penetrate the mantle. By contrast, the drills under development for Mars will have motors that operate with the equivalent power of an electric can opener.

Last February, Dohm and other scientists joined two teams of engineers from Swales Aerospace of Pasadena, California, and Maryland's Raytheon/UTD, at the Idaho National Laboratory (INL) in Idaho Falls to test two candidate drills for Mars. The rigs' designs were at opposite ends of current development in low-power, low-mass drills to retrieve core samples and cuttings for analysis.

Mars is hundreds of millions of miles away, with a radio lag time of more than 10 minutes, so Earth monitors could not react to real-time changes in drill vibrations and sounds.

Swales' entry, which has a target depth of 65 feet, used a custom-made drill string: interconnecting pieces of pipe that make up the ever-lengthening shaft of a drill. In a drill string, the shaft is assembled in sections, which are added as the borehole deepens. To collect a core sample, the entire string is withdrawn from the hole and disassembled.

Raytheon/UTD's rig, which had drilled through limestone to a depth of 4.5 feet in lab tests, used a tethered corer design. The core and cuttings are winched up from the bottom of the hole inside of the drill and collected at the surface. The advantage of the tethered system is that it reduces the weight of the drill because there is no drill string. That allows for greater depths to be bored with less energy.

Drilling conditions in Idaho Falls that February day were in some ways tougher than on Mars. Adjacent to an INL parking lot, the teams set up custom-

Planetary geologist James Dohm of the University of Arizona examines a map of Mars, where scientists hope someday to send landers or rovers that can bore beneath the surface. Off-limits, for now, are the Martian poles, where scientists believe liquid water, and perhaps life, may be found no more than three feet down.

RAYTHEON

JPL

NASA is testing a variety of drills on Earth to determine their suitability for use on the Martian surface. Drills from Raytheon/UTD (left) and Swales Aerospace (right) were tested recently outside the Idaho National Laboratory in Idaho Falls. The drills have to be capable of boring and delivering core samples and cuttings to onsite instruments that can analyze them.

LORI STILES, VA NEWS SERVICES

made white canvas tents that flapped like sails under blue skies and wispy clouds. The tents protected the teams from both stiff winds and prying eyes. But an unusual weather pattern pushed daytime temperatures to the mid-50s, causing snowmelt to flood the ground and pour into the boreholes. The regolith kept collapsing, and anyone who stepped off the hastily laid plywood footpaths would find himself ankle deep in Idaho mud. "Quagmire" came to mind, a term that shouldn't normally apply to Idaho in midwinter.

Both drills had uniquely designed bits to bore into ice or very hard rock, but not the soupy two-foot-thick layer of gravel, sand, and soil that formed atop the basalt bedrock.

The Swales team has been developing its Modular Planetary Drill System since 2005. "You want to have a cool acronym— we don't," said Argie Rumann, a senior systems engineer, in a notable attempt at humor during an intense week of field tests.

Swales brought a third-generation rig that measured 11 feet tall, four feet wide and weighed 425 pounds with its ground support equipment platform. To work on Mars, a shallow drill would need to shrink in all those dimensions by a factor of 10. The drill and retrieval system, as well as the instruments to analyze the Martian samples, would need to fit in a space of about 35 cubic feet—the size of a kitchen stove—and weigh less than 88 pounds.

Rumann, along with team leader Jose Guerrero and colleague Dominic Wu, piled dry ice and sandbags around their borehole to keep the meltwater at bay. Guerrero designed the patented bit, a donut-shaped cutting head that collects a core while the flutes spiraling up the outside deliver the cuttings into a separate collection chamber.

With the drill inching down at 50 rpm, they finally got into the basalt at a depth of 17 to 24 inches. The tent pulsated with vibrations and the drill string howled like a couple of coyotes. As drillers will tell you, there is an art to listening to the down-hole sounds of the drill string that they claim is vital to anticipating problems. Ignoring the warning sounds could result in an irretrievably stuck drill. But Mars is hundreds of millions of miles away, with a radio lag time of more than 10 minutes, so Earth monitors could not react to real-time changes in drill vibrations and sounds. Software must be programmed into the drill to stop it when sensors detect problems with torque, temperature, or other conditions.

"Developing the software to evaluate what the drill is doing and to react [to it] will take a team of programmers a year," Guerrero said. Much easier is miniaturizing the drill and its scientific instruments. That, he says, "is just a matter of money. The more we spend, the easier it is to get lower weight."

The Raytheon/UTD tethered core drill turned out to have its own problems. Jennifer Farrand and Matt Tucker, a couple of young, serious engineers, brought the drill from Maryland after 18 months of development. Their drill has an assembly that anchors itself to the sides of the hole and exerts force on the bit from down-hole instead of from the surface.

But on that unseasonable February day, the saturated Idaho regolith collapsed and captured their bit. The ground then refroze during the night. That forced Farrand and Tucker to rent an electric impact drill and bore by hand a series of holes around their stuck core until they could dig it out. Farrand took it in stride: "These conditions may arise on Mars if drill bit friction thaws ice beneath the surface. The refreezing could capture the bit permanently." She smiled, "We're always learning."

The Raytheon/UTD drill is similar to a NASA/Baker Hughes Mars drill rig that Jeffrey George and his team at the Johnson Space Center tested in the Canadian arctic in May 2006. George's team spent two weeks on Ellesmere Island testing their seven-foot-tall by 1.75-inch-diameter drill in what the scientists considered ideal weather.

"It averaged 18 below Celsius (–3 Fahrenheit) and

SWALES AEROSPACE

Basalt, like this core from the Swales Aerospace drill, is a common crustal material on Earth, the moon, and Mars. The hard, black volcanic rock is one of the barriers on Mars that autonomous drills will have to penetrate to learn more about the planet's past.

Unwelcome Visitors

ONE OF THE BIGGEST FEARS of planetary scientists who want to use robotic spacecraft to drill on Mars is the accidental introduction of Earth bacteria into the Martian surface.

"Current technology for decontaminating spacecraft is primitive," says Arthur Lonne Lane, principal scientist of the Astrobiological Group at NASA's Jet Propulsion Laboratory in Pasadena, California. "We wipe things down with alcohol, that's about it."

More severe measures – such as baking a spacecraft to temperatures necessary to kill any Earth organisms – could destroy the spacecraft's solid-state circuitry and delicate instruments needed to operate on Mars.

One process NASA is looking at, called plasma cleaning, has been used for at least 20 years in the electronics industry to sanitize components that require high connectivity, such as semi-conductor wafers. Plasma cleaning uses no solvents. Rather, a gas such as oxygen or air is electrified to form ions and free radicals that bombard a surface, scrubbing away contaminants. Done in a vacuum, the cleaning process can occur near room temperature so that heat damage is not a concern.

Until NASA can solve the problem of sterilizing its spacecraft, the space agency is taking no chances with its Mars-bound fleet of robotic explorers.

The Phoenix Mars Scout lander, scheduled to reach Mars in May 2008, will try to land at 70 degrees north latitude, equivalent to the middle of Greenland on Earth. But the spacecraft is prohibited from digging where there might be water within three feet of the surface because of concerns by scientists over planetary contamination.

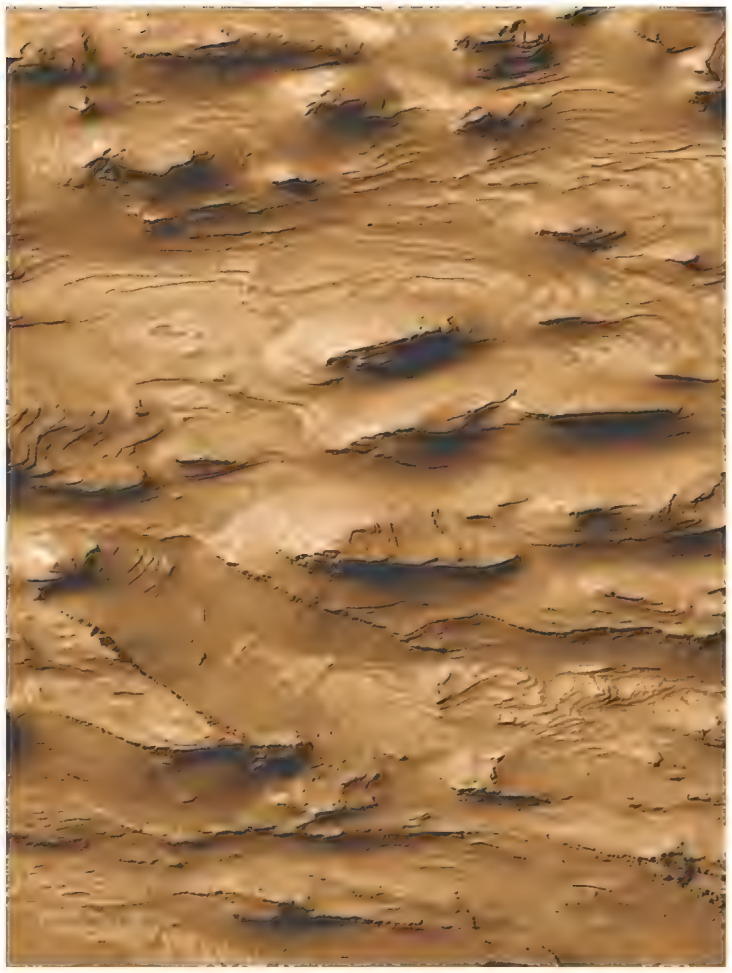
"One little strand of RNA or DNA that we transported would negate the whole test and analysis, essentially the whole mission," Lane says. "We absolutely don't want to introduce to Mars anything that could replicate. Decontaminating to the level we must, to look for life on Mars, is unachievable now."

NASA

A prototype of NASA's Phoenix Mars Scout stretches its 6.6-foot-long arm to scoop soil at Death Valley National Park in California. On Mars, the probe will dig a trench up to 20 inches deep to analyze the history of surface ice.

Earth bacteria are believed to be capable of surviving for a long time in space. The robotic Surveyor 3, which was not sterilized before launch, landed on the moon in 1967. When the Apollo 12 crew brought back Surveyor's TV camera in 1969, NASA found living microorganisms in a piece of foam inside the camera. As a result, the agency adopted stricter protection standards for its spacecraft. Some scientists, however, suggested that the only positive detection of life among 33 Surveyor samples could have come from accidental contamination of the camera after it was returned to Earth.

Until contamination concerns for Mars can be resolved, scientists may focus less on looking for life-forms or water and instead go after rock samples that could reveal new insights into the planet's evolution.



MALIN SPACE SCIENCE SYSTEMS, MGS, JPL, NASA

Eroded plains on Mars (above) are familiar to scientists; the bigger mystery is what lies underneath. Swales engineer Jose Guerrero (opposite) inspects his company's drill.

we found new ways to break and get stuck, and new failure modes and we spent a lot of time in the weather station, working on the drill. We finally drilled through ice and sandstone to two meters. We could drill about five inches in the sandstone in 20 minutes using 50 watts," George said upon his return to Houston in mid-May. The NASA/BH drill has three motors – one to anchor the bottomhole assembly, another to apply down pressure, and the third to provide torque. As with the Raytheon/UTD rig, the drill winches up the cores and cuttings through the drill stem to be collected and analyzed on the surface.

"An interesting aspect of the core samples we got was that with all the concern about contaminating them with pieces of the bit, we now know that the interior of the core is intact and uncontaminated," George said. "We trust that would be true on the moon or Mars" (see "Unwelcome Visitors," left).

After seeking the most extreme Earth environments in which to test the drill, a return to the moon may provide the best opportunity to test Mars-bound rigs. The moon would provide "fantastic field-test opportunities," says Suparna Mukherjee, technical lead for the Subsurface Access Base Technologies office at NASA's Jet Propulsion Lab in Pasadena, California. When Mukherjee talks about inventing hardware for Mars, she occasionally arches her eyebrows and utters a contralto "cool." She explains the meaning of Technology Readiness Levels 1, 2, and 3.

"TRL 1 is the draw-it-on-napkins level," she says.

MONTE LA ORANGE/POST REGISTER

"It's physics and dreaming of possibilities." TRL 2 finds scientists prowling hardware stores for off-the-shelf parts that become components for prototype systems. "The drills we tested in Idaho were TRL 3. We've gone from idea to hardware to proof-of-concept through field experimentation," says Mukherjee. "You get hooked on the challenge."

The most mature TRL 3 machines can drill through hard rock with less than 80 watts and bring samples to the surface. The next few hurdles for Mukherjee and the half-dozen other groups developing extraterrestrial drills is to miniaturize the rigs and get them to run autonomously. The drills also have to deliver samples to on-site instruments for analysis. "The mechanical engineering, with the various teams approaching problems from different angles, will be accomplished," Mukherjee says, confidently.

Scientists from NASA's Ames Research Center this summer ventured to the Canadian arctic to see whether artificial intelligence could control a Mars prototype drill. The Drilling Automation for the Mars Exploration (DAME) project bored into the Haughton Crater on Devon Island in Canada's Nunavut Territory in late July to see if synthethic brainpower could keep the rig drilling for hours at a time without human interaction. The drill, built by Honeybee Robotics, ran on its own for a cumulative total of 43 hours, with the longest shift at 4.5 hours, and bored down 10.5 feet. Operating on 100 watts of power, the drill's software also correctly responded to five of six known major fault modes. The experiment will help in designing drills for Mars, where robots will probably be able to "talk" with controllers on Earth only once or twice a day.

Mars is in many places covered with a kind of "organic crud." The deepest any spacecraft has penetrated that crud is about 10 centimeters—just under four inches.

In a briefing at the Idaho National Laboratory last February, Arthur Lonne Lane, principal scientist of JPL's Astrobiological Group, brought up several ancillary issues that NASA faces before sending drills to Mars. Data from the European Space Agency's Mars Express orbiter has shown NASA places where it does —and doesn't—want to drill.

Scientists would love, for example, to drill at the polar ice caps, where radar surveys by Mars Express indicate that water may be found just three feet down. But engineering hurdles prevent that, for now. NASA's next rover, the Mars Science Laboratory, scheduled to be launched in 2009, will carry equipment to bore into rocks. But the spacecraft is restricted to landing 60 degrees north or south of the equator, partly because the frozen ground at the poles could hinder the heavy rover's movement.

Lane speaks eagerly about the possibility of studying Martian biology, while acknowledging the frustration of looking at the planet. Mars, he says, is in many places covered with a kind of "organic crud." The deepest any spacecraft has penetrated that crud is about 10 centimeters—just under four inches—when a wheel on NASA's Opportunity lander was purposefully spun to make a trench in February 2004. The rover then pointed spectrometers into the trench to analyze heat signatures and minerals, and found spherical, glass-like pebbles the size of BBs.

The rewards of drilling on Mars are uncertain and nearly impossible to calculate. Boreholes on Earth—whether for oil, gas, or something else—are expected to pay off right away in new resources or scientific information. It costs about $20 a foot to drill a six-inch diameter water well on Earth. Drilling a two-inch diameter hole on Mars that just might turn up fossilized life? Priceless.

WEIGHT WATCHERS

How a team of engineers and a crash diet saved the Joint Strike Fighter.

On April 7, 2004, the most expensive, ambitious airplane project in history screeched to a halt. Thousands of Lockheed Martin employees tasked with creating the F-35 Joint Strike Fighter found their daily routines broken by a crisis. It had been quietly building for months as engineers cast wary eyes on the weight projections, particularly for one of the three JSF variants, a short-takeoff/vertical-landing fighter. With each review the problem was becoming more evident: The F-35B STOVL fighter was nearly 3,000 pounds over its projected weight.

Lockheed declared April 7 "Stand Down Day," using a military term that signals the grounding of a fleet for an emergency safety review. Anyone working on any part of any of the variants was called in to a meeting and given the grim prognosis—four years into the 12-year, $276 billion development program, all work would stop until the JSF dropped some weight.

In Washington, D.C., program managers in the Pentagon had "a fair number of soul-searching meetings in the Department to see if we'd ever fix the program," according to Rear Admiral Steven Enewold, at the time the program executive officer at the Joint Program Office (JPO), which manages the JSF effort for the Department of Defense.

BY JOE PAPPALARDO | PHOTOGRAPHS BY ERIC SCHULZINGER

"There was a belief we could get a lot of the weight," he says. "But there was a disbelief we could get it all." One team of independent reviewers anticipated that at best, only two-thirds of the excess weight could be redesigned out of the aircraft.

Inside Lockheed Martin's Fort Worth, Texas facilities, a squad of 550 engineers was formed to do the liposuction. Most of the weight was in the airframe, but with thousands of extra pounds to account for, the innards of the JSF also had to be redesigned. It was everybody's problem. Directed by about a dozen team leaders, each plucked from his or her area of expertise (airframe, mission systems, engines, and so on), the engineers called themselves the STOVL Weight Attack Team, or SWAT.

Before the team was formed, the SWAT engineers had been watching the penalties imposed by the extra pounds. The F-35B was busting specs on landing speeds, especially in cases where a pilot returned with a full load of unexpended ordnance.

"There was a lot of agreement that the program was in a critical stage," says Art Sheridan, the current director of F-35 affordability at Lockheed. With SWAT, "the company was putting its money where its mouth was," he says.

Sheridan knows the F-35 very well. Hired in 1979 as an aerodynamicist by General Dynamics, he has worked at the Texas plant ever since, eventually becoming chief of all STOVL projects. Since 1995, he has served in a slew of positions with the F-35 development team. He was also responsible for analyzing the X-35 flight test data during the JSF contest with Boeing (see "Winner Take All," Dec. 2002/Jan. 2003).

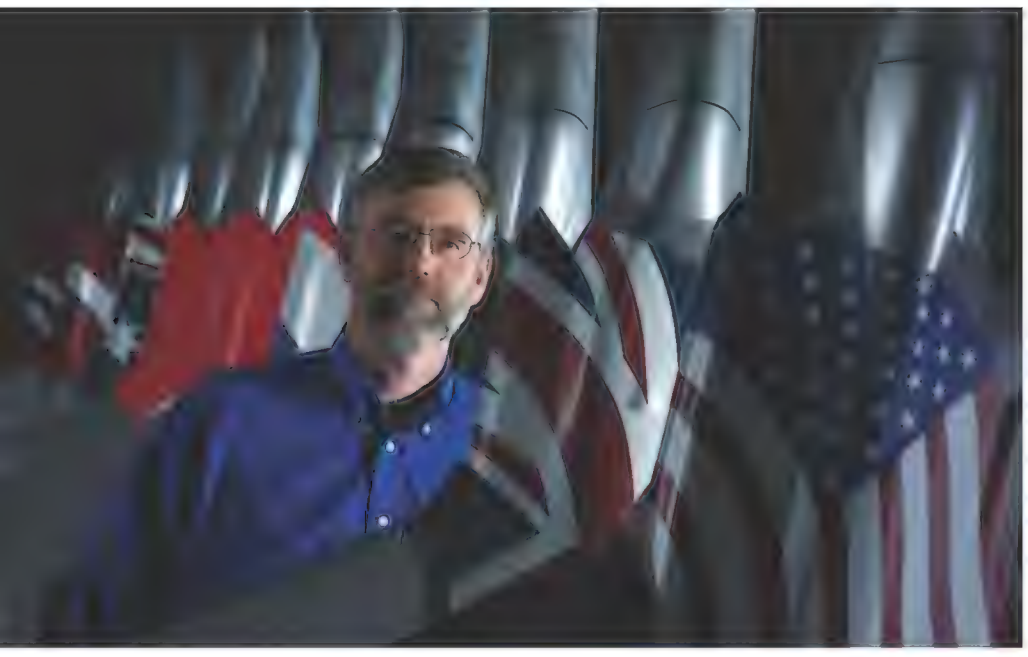
In April 2004, Sheridan was named leader of the ad hoc SWAT team. The future of the F-35 program and of Lockheed Martin's stake in military aviation rested on his slight, stooped shoulders. "I had been very vocal about the weight issue [during 2003]," Sheridan says now, a grin stretching the curved geometry of his ash-white beard. "Maybe the way to get back at me was by making it my problem."

OPPOSITE: COURTESY LOCKHEED MARTIN

The 30,000-pound X-35B hovers in July 2001. While its descendant geared up for production, its weight crept toward obesity.

AT 8:15 A.M., A FLOW OF vehicles and people steadily pours into the Lockheed Martin Aeronautics plant, located just outside Fort Worth in the town of White Settlement. Roughly 16,000 employees here design and assemble some of the world's most complex aircraft. There is a high ratio of blue jeans to suits. These are not the corporate types of the company's Bethesda, Maryland headquarters, but the brainy designers and blue-collar assemblers of the defense contractor's products.

The pre-World War II facility, formerly U.S. Air Force Plant Four, has seen the birth of tens of thousands of aviation legends, from the B-24 to the F-16. It has also wit-



ERIC SCHULZINGER AND DAN AUBER

Lockheed's Art Sheridan says he was outspoken about the weight problem. "Maybe the way to get back at me was by making it my problem."

nessed expensive stillbirths like the A-12 Avenger. SWAT's job was to keep the F-35 in the former category.

The cornerstone of the company's future military aviation business, the F-35 is a complex undertaking: A worldwide network of partner contractors and subcontractors produce components that are assembled in a section of a mile-long building in Texas. Shared three-dimensional electronic design files are updated daily to keep each engineer working on the most current version. At the Texas plant alone, about 4,500 employees work on the three JSF variants, each with unique requirements and capabilities to suit the various needs of three finicky U.S. armed services and more than a handful of skittish international partners. For affordability's sake, however, the variants must be largely—up to 80 percent or so—identical. Because of the high degree of commonality, modifications to the design of the portly problem child can be applied to the other two versions.

One challenge in designing stealth aircraft is that all stores—extra sensors, fuel tanks, and weapons—must fit internally. Anything hanging outside of the aircraft will increase the aircraft's radar cross-section and thus diminish its stealthiness.

On the F-35 STOVL variant, the F-35B, the weapons bays must share internal space with an enormous lift-fan engine, which enables the vehicle to hover and land vertically, and with the engine's ducts. The wide cavities demanded for these components contribute to weight gain because they compromise the best layout for the aircraft's load-bearing structure. Creating an airplane around these systems is akin to designing a human skeleton after the organs have been installed. It forced the airframe team to adopt a heavier design.

The program's initial focus on affordability also added weight. Off-the-shelf parts cost less but weigh more because they are not optimized for a fighter. To get bulk quantities of replacement parts for a lower cost might require using a heavier component. It soon became obvious that the plan to use common parts among the variants—a strategy that would lower costs and streamline future maintenance demands—was also bulking up the F-35.

Initial estimates of how much a part will weigh are based on its volume and material. But they are just estimates; the actual weight is another matter. A heftier hose, a wider screw, a thicker panel—in dribs and drabs, the weight steadily increases.

Even in a world of precision design tools, weight estimates still depend on data from previous aircraft. That turned out to be a problem as the crowded interior and the demands of the design translated into poundage. "Legacy estimating techniques just don't work with this family of airplanes," says R.J. Williams, Lockheed's vice president of F-35 Air Vehicle Development.

Art Sheridan says that cost, not weight, was the most important measurement during the early history of the program. "The focus was very much on affordability at the time," he says. "People realized there was a penalty to be paid, and that was included in the weight estimates. It was higher than we thought."

No matter the reason, when weight became the enemy, the SWAT team concentrated its effort on reducing it, as well as reducing the bureaucratic hoop-jumping that can slow a redesign. "The number one commitment was to remove obstacles and make quick changes," Sheridan says.

Instead of the typical series of boards that normally reviewed proposed design changes, SWAT consolidated the process into one review panel. Engineers were expected to come in with an idea, face detractors, and accept a decision in one sitting.

"You're not supposed to come in with a white coat on," says Sheridan, and suddenly his face and voice become stern, presenting the manner he used to get the job done. "You're supposed to come in with a way to make it happen."

An important attitude change was realizing that all weight savings—a pound here or a dozen pounds there—were vital. According to the database of incorporated SWAT changes, the average recommendation averaged only six pounds. But by taking "only" out of engineers' mindsets, more and more ideas were considered.

Lockheed engineers like Santi Bulnes, of F-35 Mission Systems and a SWAT team leader, were given a free hand to redesign. "They said, 'Forget what equipment is in the way. Draw it like you want it,' " he recalls.

The process also required a change in parochial attitudes and a willingness to put a finished design up for review, SWAT participants say. No one likes his work questioned, but no one wants a redesigned part to fail, possibly costing lives. Due to the interconnected nature of the airplane's interior, some new designs required

Engineer Santi Bulnes says he was given plenty of leeway to redesign – almost a back-to-the-drawing-board mandate.

COURTESY LOCKHEED MARTIN

An F-16 flies chase on the X-35C. Some weight-reducing design changes for the B variant were also applied to the A and C, both of which shed 1,300 pounds.

changing perfectly sound ones.

"People are proud of their designs. There is not too much interest in other people's problems," says Sheridan, flanked by SWAT team leaders in a Lockheed conference room. Each of the engineers—including Sheridan—had original designs abandoned during the redesign. "It's a transformation from feeling good about protecting yourself to the exhilaration of pushing that margin out," he says.

If "exhilaration" seems like a strong word to describe the process, it helps to understand the engineer's mindset. A radical redesign under extreme time constraints is as challenging as the field gets. "It's not often you get to spend your days with that talent pool and work problems like that," says Bulnes. "We probably won't see it again in our careers."

JOE LECOMPTE WAS a 24-year-old rookie electrical power system engineer on Stand Down Day. His job at Lockheed was his first after graduating from Louisiana State University.

The meetings began only after employees were given some time to think. From the first order—"Everyone go to your cube [to brainstorm] and don't bother anyone"—he felt grateful to be included in the rescue. "I felt really informed," LeCompte says. "They had charts showing where the program needed to be. It wasn't like smoke and mirrors."

Managers that day announced the financial rewards to be paid when weight-loss ideas were accepted: $50 an idea and an equal amount for every pound the idea removed. The bounty was later increased to $100 an idea and $500 per pound.

The mix of candor, pressure, and incentives paid off: Something "did occur to me on Stand Down Day," LeCompte grins. What occurred to him was to remove a power panel from the right-hand weapons bay by modifying another to handle the work. If realized, the modification could reduce overall weight by more than 20 pounds.

Four months later, LeCompte was called to a SWAT board meeting, where senior Lockheed officers said his idea would be included in all three variants. They awarded him $13,000. LeCompte used the money to close on his first home.

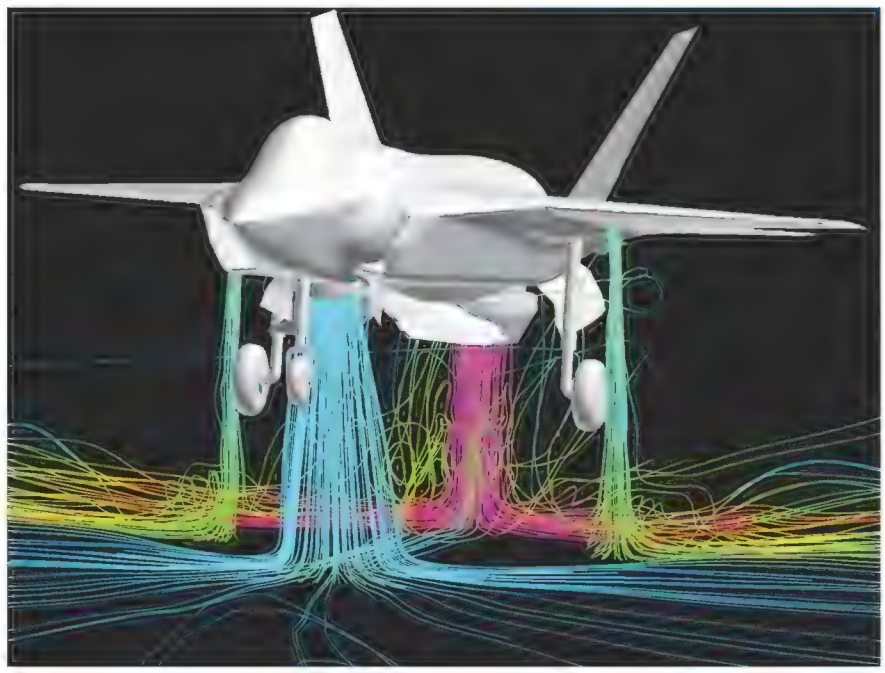
He says he also felt the satisfaction of directly contributing to the final design of the 21st century's first new fighter, which, thanks to him, has a reconfigured power panel, as well as three other improvements he suggested, each of which removed about a pound.

It's one thing to hear company officials speak of a "change in culture" among staff; it's another to hear it from a fresh-faced 26-year-old. "People realized a half-pound was worth something," LeCompte says. "Even today, if you're working an issue and you mention weight, it gets everyone's attention."

The deluge of ideas—more than 2,000 were suggested on

ERIC SCHULZINGER AND DAN AUBER

The cooler (blue) airflow beneath the F-35B is from the shaft-driven lift fan, which ingests ambient air and expels it without significant heating.



COURTESY OF ERIC GUNDERSEN / LOCKHEED MARTIN

Motor Mafia to the Rescue

ONE SACRED COW that could not be touched directly during the Joint Strike Fighter weight loss effort was the engine. Although it offered an easy solution — add thrust to counter the weight gain — that was seen as a one-shot dodge that would only mask the problem.

The Lockheed propulsion team — the "Motor Mafia" — got to work. "We knew there were several things we could tweak to increase thrust but not make the engine work harder," recalls J.D. McFarlan, the former propulsion team lead at Lockheed, since promoted to Air Vehicle Development Deputy. Pratt & Whitney's engine was operating as promised, and changes could be expensive, time-consuming, and potentially detrimental to the product's lifespan.

The first idea was to reshape the auxiliary inlet for the lift fan. By increasing the amount of incoming air, engineers increased the engine's efficiency. Only half the air that the STOVL lift fan requires will come from the main air inlets, located on the airplane's lower flanks. The rest comes in through an opening in the top, behind the cockpit.

Pratt & Whitney, which supplied the engines during development, is squared off against General Electric/Rolls-Royce over the contract for engines for the F-35 fleets. (The Department of Defense wants to cut GE from future consideration, prompting an international outcry. The final disposition is pending.) To find a solution to the weight problem, experts from Pratt & Whitney met with Lockheed propulsion engineers as well as their rivals.

Engineers eyed the lift-fan nozzle, which swivels downward for hovering and landing. The F-35B was not as good at hovering as its experimental predecessor, the X-35. The X-35 had a nozzle with divergent section length, from throat to exit, of just seven inches, three times shorter than a typical section length.

The Motor Mafia lengthened the F-35B's nozzle divergent section to 16 inches. To keep it from hitting the ground when it swiveled, engineers shortened the three-bearing device that swivels the nozzle. At the point where it joins the aircraft's body, the nozzle could be reduced two inches in diameter by consolidating the layout of its gears and actuators. Hover performance was improved by reducing the area of the nozzle exit.

"Both engine makers had to share a fair amount of information," McFarlan says of GE and Pratt & Whitney. "You get a lot of information [about] the engine's output, on strengths and weaknesses. [Collaboration] is traditionally not done.... But there was a good recognition of the importance of integrating the design."

COURTESY LOCKHEED MARTIN

The X-35A, built to validate propulsion and flying qualities for the Joint Strike Fighter, takes flight in October 2000.

Stand Down Day alone—initially overwhelmed Lockheed's F-35 managers. To smooth the process of the redesign, they created a permanent Weight Improvement Program to assess ideas and pay rewards. Staff ffrom every office became "dieticians," studying every conceivable part on the aircraft for weight.

Steven Twaddle, a materials engineer, realized that he could reduce the surface area of thousands of nut plates by using a high-strength adhesive, which saved 21.5 pounds. Aircraft performance senior staff engineer Brian Losos, who has worked on the JSF since 1995, came up with an idea to change the landing gear housing. Instead of a single door opening from the side, he suggested a two-door clamshell design. It would increase the weight, but the aerodynamic effect of removing the single dangling door, functioning as a sail in crosswinds, would allow a reduction in the size of the two tail fins. The change garnered him a $15,000 bounty.

By the end of February 2006, Lockheed Martin had paid out more than $1.2 million to employees for ideas. The cost is considered minimal compared to the benefits, says Greg Henderson, the inaugural director of the F-35's Weight Management and Control office at Lockheed.

ERIC SCHULZINGER AND DAN AUBER

Propulsion whiz J.D. McFarlan shows off the monster Pratt & Whitney F135 engine that will power the F-35 on its first flight, to be made later this year. Below, the first F-35A nears completion in late 2005.

2006], we've held that flat. It's historically unprecedented."

Indeed, skepticism still lingers within the Joint Program Office. After all, it is the job of that office to remain alert to problems. "It was successful in that, for now, we kept the weight off," says Enewold. "My parting shot is that I'm cautiously optimistic the weight will stay out."

WHILE LOCKHEED MARTIN engineers struggled to trim the F-35's weight, they also fought to protect the airplane's performance. However, some concessions had to be made, and Art Sheridan says that members of his team reluctantly approached the defense department with requests to relax some requirements during the redesign. Sheridan calls it "a last resort." Until engineers can prove why their efforts at another solution failed, he says, a suggestion to diminish performance is bound to go nowhere.

At SWAT's request, plans for the F-35B to carry a pair of 2,000-pound bombs internally were returned to the aircraft's original specification of two 1,000-pound bombs. The requirement to carry two internal missiles alongside the bombs went unchanged.

COURTESY LOCKHEED MARTIN

Whereas the SWAT team had the chance to reconfigure the entire airplane, "the configuration is now fixed," Henderson says. "Now we ask: What's the lightest way to make it? Every hole and flange is looked at."

Hiring Henderson to oversee the effort, and ultimately making the position permanent and directly accountable to high-level company officials, proved how serious Lockheed Martin believed the weight problem to be. Henderson says a high-level position dedicated solely to weight issues is unique in the industry.

Part of the weight management office's job is reaching out to suppliers. "Post-SWAT, we have to contend with the milling and grinding," says Henderson. Experienced structural engineers visit supply shops with ideas on changing designs to cut weight. Subcontractor efforts shaved 586 pounds during SWAT.

Keeping the pounds off requires diligence. The weight control office has to combat "bounce back"—the tendency to put pounds back on after they've been lost, a familiar pitfall of many a human diet. "They said it was hard to take thousands of pounds of weight off the aircraft," Henderson says. "But it was considered impossible to keep it off.

"Many of the graybeards said, 'You're not going to be able to hold it,' " adds Henderson, now president of the Society of Automotive Engineers. "But between October 2004 and now [May

So how does an engineer ask the Pentagon to be flexible? First, keep the military in the loop. Show a graph with the progress so far. Then, according to Sheridan, present the stark truth: "You can look at this requirement, or would you rather not have the program?"

The game of aircraft design is one of tradeoffs, which inspires differences in opinion. Giving everyone within the JPO a say in the redesign would be a recipe for disaster. "No one person's opinion could grind us to a halt," says John Hoffschwelle, a SWAT leader and director of F-35 Air Vehicle Definition.

Sheridan says it was a matter of keeping the JPO informed

ERIC SCHULZINGER AND DAN AUBER

Brian Losos added weight by altering the landing gear housing, but the resulting reduction in tail size produced a net loss.

imum G forces the STOVL could pull, for example, but the JPO insisted it stay at 7 Gs. An attempt to remove some fire suppression generators was also nixed. "Even since then [SWAT], we've made some design changes that add a little weight," he says.

Performance had to be guarded, but the government also wanted to control cost. The F-35 started as the most expensive warplane in history—no one wanted the price tag to increase.

Military customers fretted that the airplane's maintenance and logistics demands would increase due to the redesign. In response, SWAT included the impact on these parameters in its database of design changes. "We didn't have those constraints," Sheridan says. "But we definitely kept an eye on them.... [The JPO] had fear we were going to trash supportability."

A major blow to the JSF manufacturing concept, leading to an increase in production costs, was the abandonment of "quick-mate joints." The idea was to attach interlocking parts to individual components that would make the final assembly of the fuselage, wings, and engine easy, like snapping and soldering jigsaw puzzle pieces. But the interfaces drove the weight up by about 1,000 pounds, so a traditional, time-consuming joining system was adopted. All three F-35 variants lost their quick-mate joints to preserve production commonality.

The JSF team had earlier hatched a new idea to cut cost—use "cousin parts" instead of the sometimes heavier common ones. The concept was going to be applied to trim weight as well as cost.

A full-scale mockup of the F-35 is poised in the assembly area, which Lockheed says will eventually crank out an airplane a day.

A cousin part is manufactured using the same machine, but the computational design information is altered to produce a part unique to a variant. If a part is designed to handle certain stresses arising only during a carrier landing, it can be remade with the same tool for the conventional takeoff-and-landing variant, with only a minor cost increase. A commercially available part can be shaved to save room, offering, in some cases, a direct route for a hose rather than a circuitous one. Less hose equals less weight. Unique items cost more to manufacture and to replace, but the weight savings sometimes necessitated the higher cost.

Enewold says the production cost of F-35s has risen slightly due to implementations of SWAT plans. The effect on supportability cost is yet to be seen.

of all changes but limiting JPO involvement as much as possible. "They weren't really voters" during SWAT, Sheridan adds. Some less diplomatic engineers call it "helping the customers control themselves."

From the Pentagon's perspective, there was little choice. The STOVL was not going to fly as designed, and the design talent was all locked up in Lockheed and the other contractors. "The truth is, they have the knowledge," says Enewold. "When we decided we needed to go after weight, we said [to contractors], 'There is nothing restricted in what you can look at.' "

Still, he adds, the JPO needed to get some decision makers on the scene during the redesign to provide "sanity checks on trades" that were being suggested. A dozen colonels, majors, and upper-level civilian managers stayed in Fort Worth through 2004 to analyze solutions and sign off on program-level changes, something the usual retinue of about 20 JPO liaisons at Lockheed could not do.

Some half-dozen SWAT ideas were rejected, Enewold says. Lockheed engineers suggested reducing the max-

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SEE THE X-35B make a short takeoff, hover, and land vertically and read about its new home.

Last July, U.S. Air Force Chief of Staff General T. Michael Moseley announced the F-35's official name: Lightning II, in honor of an earlier Lockheed triumph, the P-38.

IN OCTOBER 2004, the Defense Acquisition Board signed off on more than 500 recommendations, officially making the STOVL weight loss attack team a success.

In eight months, the Lockheed engineers cut a total of 2,700 pounds from the F-35B. The effort also trimmed 1,300 pounds from the other variants. Comfortable with that legacy, SWAT faded, with accolades, into company history, but an estimated 20 ideas a week still turn up in the Weight Improvement Program office.

Design and assembly changes, mostly related to the SWAT recommendations, have cost about $4.8 billion—part of a $6.2 billion replanning to accommodate the additional design cycle required to make the improvements. The replanning forced an 18-month slip in F-35 deliveries. According to a 2006 Government Accountability Office report, since inception, the development costs of the JSF program have increased 84 percent and its timeline slipped by about five years. The STOVL's final delivery deadline has been extended two years, to 2012.

When AA-1, the first CTOL F-35, rolled out of the assembly building on a gray, misty morning last February, it featured none of the SWAT-era optimizations. The weight of this F-35A is greater than what was originally projected, but not so high that the aircraft does not meet key performance parameters, Lockheed officials say. The margins would be very tight—they are not wide, even with the redesign—but it would have made it. Every F-35A that follows will be lighter.

"Weight's going to be a focus item for this program for the rest of its life," notes Enewold. He adds that until flight tests are completed, he will worry that the diet has removed some of the aircraft's "good weight"—the structure that makes the airplane durable. A former Navy pilot, Enewold knows well the punishment an aircraft suffers during carrier operations.

The future of the F-35 is clouded by political battles, international diplomacy, the availability of titanium, a test schedule that overlaps production timetables, and U.S. government worries over transfer of technology to foreigners. But with SWAT, the program has a chance to come to fruition. Without that team, the sight of an F-35B hovering over a carrier deck would have remained the creation of a company artist, relegated to a poster decorating a corporate conference room.

Engineer Joe LeCompte shaved more than 20 pounds from the F-35's right-hand weapons bay. He used the reward money to close on his first home.

ERIC SCHULZINGER AND DAN AUBER

A Trip to Australia Reveals the Wonder of Giant Golden Pearls

Just before 1900, in a small isolated town called Broome Australia, fishermen came across the rarest oyster—a giant named the Pinctada maxima. This world's largest oyster contained the voluptuous South Sea Pearl—the most sought after pearl in the world. After this discovery, Broome soon became the dominant pearl trading post in the world and literally 80% of all worldwide pearl trading passed through Broome.

A trip to Broome. Our pearl buyers took the long trip to Australia to study the famous white lipped oysters that produced magnificent pearls that are often 11-14 mm—about 8 times the size of a standard cultured pearl. Not only did these oysters produce the rare South Sea pearl but they also produced tremendous amounts of mother of pearl or nacre. Nacre is the lustrous iridescent substance which is secreted by the oyster to form the shiny inside of their shells. When nacre secretions are deposited around the seed they build up to form a full sized pearl. Our bio-scientists went to work to see if we could improve upon Mother Nature's process. By extracting the pearl seed from young fresh oyster shells and applying the giant oyster's nacre by hand, our experts are able to produce the breathtaking Australian Pacific Collection.

Golden beauties. These Grade AAA rated orbs are extremely large in size-12mm—but they are much more consistent in shape than ordinary pearls that have to be extracted from 4-5 year old oysters that are dead. They are also less porous so you don't have to worry about perfumes or cosmetics discoloring like you do with ordinary pearls. In a more ecologically friendly approach, the Australian Pacific pearl seed is extracted from fresh oyster shells and then organically micro-coated in the laboratory with the same nacre that coats naturally grown pearls. Giant 12mm golden South Sea pearls can cost up to $50,000 for an 18" strand. Why even think about that when you can now wear an 18" strand of 12mm hand coated enhanced pearls with a consistently round shape and a rare golden color for under $300.

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SIGHTINGS

Jim Bertoglio's memories of World War II are rendered in stark black and white. More than 60 years after he was assigned to chronicle the lives and deaths of the airmen of the 94th Fighter Squadron in Foggia, Italy, his photos retain their ability to connect viewers to the glory and terror of the air war in Europe.

A 19-year-old Sergeant Bertoglio (right) arrived in Foggia in May 1944, armed with a camera and dedicated to capturing the 94ths' contribution. The squadron's Lockheed P-38 Lightnings escorted bombers on runs over the Mediterranean, and were later tasked with unremitting ground attack missions (opposite, bottom). When they scrapped with German fighters, they dropped their extra fuel tanks to shed weight, a sight Bertoglio captured in a shot of a tight formation of P-38s returning to base (opposite, above). Among Bertoglio's most emotional images is that of a charred husk of a B-17 bomber that had crashed at Foggio due to pilot error (below). All 17 on board were killed; the photographer was scheduled to be on the aircraft the day it went down.

Bertoglio's photographs were widely published during the war. After the war ended, they were stored in a closet, remaining unseen for decades. Promoted by historical societies in his native Kansas, where he still works as a photographer, the photos are again being dispayed in public, including adorning a room of the Kansas State Legislature.

COURTESY OF THE JESSE DAVIDSON AVIATION ARCHIVES

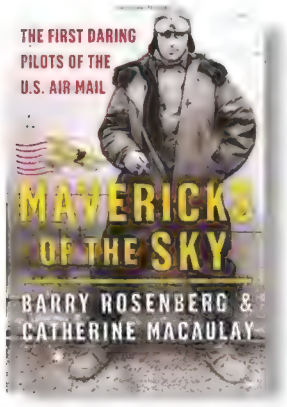
Early airmail pilots had little room for error when crossing the Rocky Mountains.

How Pilots Went Postal

Mavericks of the Sky: The First Daring Pilots of the U.S. Air Mail

BY BARRY ROSENBERG AND CATHERINE MACAULAY. WILLIAM MORROW, 2006. 341 PP., $25.95.

Two Texans, Postmaster General Albert Burleson and his departmental sidekick, Otto Praeger, brought the dream of a U.S. Air Mail Service to life in late 1918, however shakily. Congress considered air mail a joke, and the mail-carrying railroads considered it an affront. *Mavericks of the Sky* tells the story of an inauspicious beginning and of the three subsequent years of turmoil during which pilots and ground personnel died in the cause of establishing air mail service.



As the Post Office's overseer, Praeger was single-minded, talented, and resourceful, but he was also cold-hearted, under-funded, and bull-headed. He was not a pilot, but his flying rules were simple: Fly or be fired. Ignore weather that would keep Eskimos huddled in their igloos.

Praeger took three years to triumph over the railroads—with a 1921 run between San Francisco and New York that bettered the railroad's time by days instead of hours.

The authors introduce a succession of fascinating characters who flew the mail, but the tale would have been better told had Rosenberg and Macaulay used fewer clichés and chosen their words more carefully. One charts a course, not "charters" one. Events may cast a pall, not a "pallor." Misspellings included "cumulous" for cumulus, "raison d'etra" for raison d'etre, and "vicelike" for viselike.

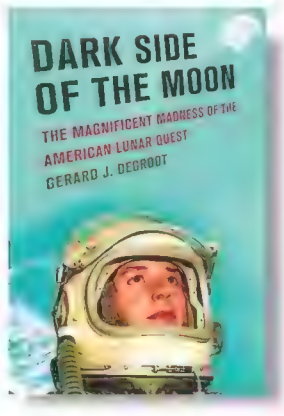
Still, *Mavericks of the Sky* is a should-read story of forgotten flying pioneers who earned their keep in the hardest way.

WILLIAM JEANES IS A FORMER EDITOR-IN-CHIEF AND PUBLISHER OF *CAR AND DRIVER*.

Dark Side of the Moon: The Magnificent Madness of the American Lunar Quest

BY GERARD J. DEGROOT. NEW YORK UNIVERSITY PRESS, 2006. 352 PP., $29.95.

In the spring of 1999, leading news organizations in the United States asked historians and think-tank researchers to rank the 100 most significant events of the 20th century: The Apollo landings on the moon muscled their way to a close second, after the splitting of the atom. Scotland's University of Andrews historian Gerard J. DeGroot, having already tackled the story of the bomb, now turns his attention to the moon landings. He begins with the valid concern that Apollo has taken on mythical qualities and is remembered with nostalgia. Such a situation begs for an antidote, and DeGroot readily offers one. Questioning the reasons for the Apollo program and criticizing the execution and results of it, DeGroot presents a poorly researched book based almost exclusively on secondary materials, and even then he misses many of the most significant of those works. While I believe it is appropriate to criticize aspects of the Space Age, criticism must be firmly grounded in the historical record.



Most of what DeGroot claims in *Dark Side of the Moon* has been argued before by other scholars, and generally those critiques are more innovative

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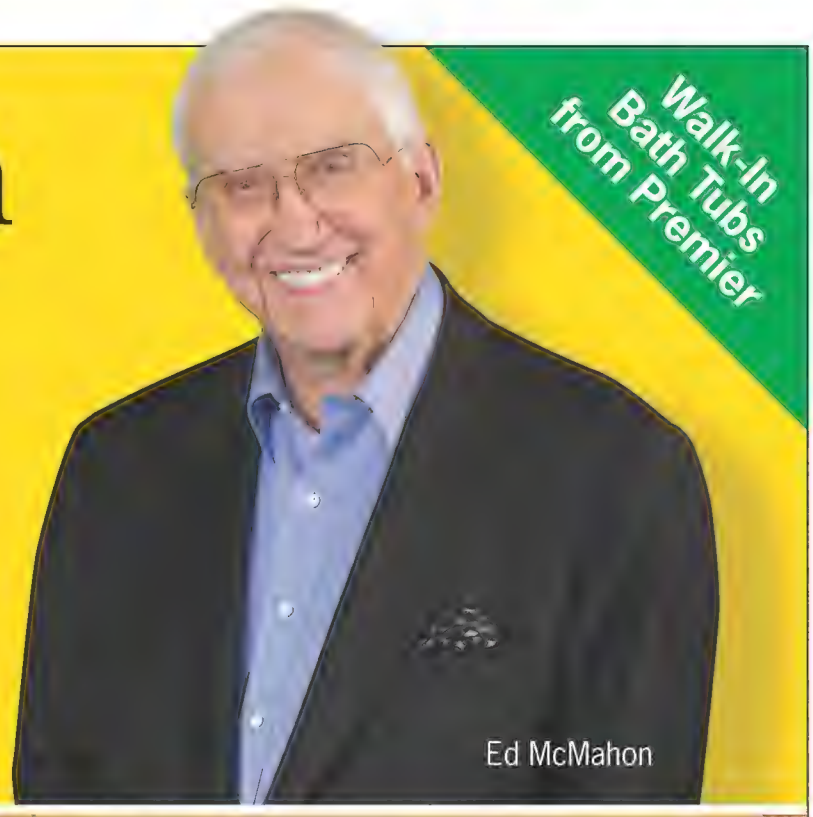

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and reasoned. Certainly DeGroot is not the first scholar to challenge the necessity of the moon race. Amitai Etzioni in *The Moondoggle: Domestic and International Implications of the Space Race* (Doubleday, 1964) offered an important critique more than 40 years earlier. Pulitzer Prize-winner Walter A. McDougall presented a strikingly sophisticated challenge of the necessity of the moon race in *...The Heavens and the Earth: A Political History of the Space Age* (Basic Books, 1985), arguing that Apollo prompted the space program to become identified almost exclusively with high-profile, expensive, human spaceflight projects of limited value. For readers interested in critiques of the space program, *...The Heavens and the Earth* is the gold standard.

DeGroot's conclusion is: "Hubris took Americans to the Moon, a barren, soulless place where humans do not belong and cannot flourish. If the voyage has had any positive benefit at all, it has reminded us that everything that is good resides on Earth." This is the ultimate arm-waving statement in a book filled with them. The question of hubris in Apollo deserves serious scholarly attention; the apparent barrenness of the moon has been challenged by scientists; and the ability of humans to survive there is very much an unknown. The claim that the trips to the moon made us see Earth anew has become trite. Such assertions, without elaboration and substantiation, abound in this book. The Apollo epic deserves responsible consideration and reflective analysis; unfortunately, *Dark Side of the Moon* provides neither.

ROGER D. LAUNIUS IS CHAIRMAN OF THE NATIONAL AIR AND SPACE MUSEUM'S DEPARTMENT OF SPACE HISTORY. THE FORMER CHIEF HISTORIAN OF NASA, LAUNIUS IS THE AUTHOR OF *NASA: A HISTORY OF THE U.S. CIVIL SPACE PROGRAM* (KRIEGER PUBLISHING, 2000).

Kids to Space: A Space Traveler's Guide

BY LONNIE JONES SCHORER. FOREWORD BY BUZZ ALDRIN. APOGEE BOOKS, 2006. 304 PP., $29.95.

Is it possible to have an aquarium in zero-gravity? Is it hard to brush your teeth when you're floating? Astronauts, NASA bigwigs, space tourist Dennis Tito, and SpaceShipOne designer Burt Rutan provide the answers to the questions American and Canadian schoolchildren have about space travel. *Kids to Space* would be a great asset to educators about to embark on a space curriculum; the book's 304 pages touch on every facet of space travel conceivable to young minds. Includes a CD-ROM of useful hyperlinks and children's artwork.

Team Moon: How 400,000 People Landed Apollo 11 on the Moon

BY CATHERINE THIMMESH. HOUGHTON MIFFLIN, 2006. 80 PP., $19.95.

Team Moon is a slick, quick, and fun read. Big photos and quotes from the little guys – NASA back-roomers and aerospace contractors – illustrate the heart-stopping moments of man's first mission to the moon: the Australian windstorm that could have wiped out TV images of Neil Armstrong's first steps, and the slug of frozen fuel that could have made the lunar module explode.

SAM GOLDBERG IS A FORMER ASSOCIATE EDITOR AT *AIR & SPACE*.

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CREDITS

A Bougainville Mystery. Paul A. Roales is a retired geologist who served as an instructor of meteorology in the U.S. Army during the Vietnam War. He now haunts estate sales and flea markets in the Tulsa, Oklahoma area for military memorabilia.

Cheap Thrills. Tom Jones is a pilot and planetary scientist who wrote about his space shuttle experience in *Sky Walking: An Astronaut's Memoir* (Smithsonian Books, 2006).

Stormbird. Douglas Gantenbein is a correspondent for *The Economist*. He also writes for *Travel + Leisure* and *Outside*.

Landing in Baghdad. Allan T. Duffin is a writer, graphic designer, and college history instructor in Los Angeles.

The Ground. Michael Behar is a freelance adventure-travel and science writer. He lives in Boulder, Colorado.

How Things Work: Aircraft Identification. Lester A. Reingold's first book, a pictorial history of the Wright brothers' hometown, Dayton, Ohio, was published last year.

The Great Warplanes. Philip Makanna's work includes four previous "Ghosts" books and a calendar series of the same name. More of his images can be seen at *ghosts.com*.

Space Trippers. Craig Mellow writes frequently about Russia and space.

The Next Little Thing. Mark Huber wrote "Mach 1 for Millionaires" (Feb./Mar. 2006).

The Not-so-big Dig. Writer Tom Harpole is a licensed blaster who has set explosives in swamps and quarries.

Weight Watchers. Joe Pappalardo is an associate editor at *Air & Space/ Smithsonian*.

Eric Schulzinger is Lockheed Martin's corporate photographer.

FORECAST

IN THE WINGS

Soaring Solitary

There's something special about seeing a unique aircraft take to the sky, especially when it's the last of its breed aloft.

© PHILIP MAKANNA/GHOSTS

Jack Northrop's N9MB was a trailblazer: one of the earliest airplanes *sans* tail.

The Ultimate Interceptors

U.S. Air Force strategists in the 1950s sought aircraft like Convair's F-106 Delta Dart and McDonnell's F-101 Voodoo to counter nuclear-armed Soviet bombers.

CALENDAR

October 8

Autumn Airshow. This year's show features vintage propeller-driven classic aircraft. American Air Museum, Cambridge, United Kingdom, phone: 44 (0) 1223 499 305, *aam.iwm.org.uk*.

November 17

Lindbergh Symposium: "Anne Morrow Lindbergh – The Woman, the Words, the Life, and the Legacy." Speakers, who include aerobatic champion Patty Wagstaff, aviation historian Richard P. Hallion, and granddaughter Kristina Lindbergh, will talk about Morrow Lindbergh's life as an aviator, navigator, and writer. Edison & Ford Winter Estates, Fort Myers, FL, (239) 334-2154, ext. 2119, *www.earthshineinstitute.com*.

Organizations wishing to have events published in Calendar should fax press releases to (202) 275-1886; e-mail them to editors@si.edu; *or mail them to Calendar,* Air & Space/Smithsonian, *MRC 951, PO Box 37012, Washington, DC 20013-7012.*

1927 Lincoln

1929 Surrender of Fort Sackville

Scarce 1926 Stamp

V-22 X-ing

SHELDON COHEN / BELL HELICOPTER

The Osprey over London.

THIS SPRING, AIR CREWS operating V-22 Ospreys stationed at Marine Corps Air Station New River, near Jacksonville, North Carolina, began planning two flights that would demonstrate one of the Osprey's prime attributes: the ability to deploy itself anywhere in the world. Prior to the development of this revolutionary tilt-rotor aircraft, military rotorcraft—helicopters—were usually sent to an operations area by airlift. The two summer 2006 flights, one from New River to Marine Corps Air Station Miramar near San Diego, California, and the second to the Farnborough Air Show in England, were the latest in a series of historic missions to illuminate the global reach of U.S. forces.

Helicopters have made long flights before: In August 1970, two Air Force Sikorsky HH-53Cs flew from Eglin Air Force Base, Florida, to Da Nang, South Vietnam, a flight of some 9,000 miles. But when Bell Boeing pitched its V-22 to the services in the 1980s, part of the deal was "self-deployment"—the ability to fly straight to the action, and to do it routinely.

The Marine Ospreys were equipped with mission auxiliary tanks (MATs) for both trips. "They're not that big a process to install," says crew chief Corporal Timothy Fleming, 25, from Cleveland, Ohio. "It's about an hour to get 'em hooked up and you're ready to go." With two KC-130Js along as tankers and Tacan-beacon-equipped ships, the Ospreys could form up with the 130s even when they couldn't see them in the clouds. The nine-hour flight from New River crossed South Carolina, then went over Memphis and Little Rock before hitting Oklahoma and the Texas panhandle. From there the Ospreys flew across the deserts of New Mexico and Arizona to Needles, California, and on into Miramar. But this was just a dress rehearsal for the big one: a July jump across the pond to England with the same crews.

Marine Major David L. Lane, 38, of Paris, Arkansas, flew one of the two Ospreys and did the planning for the flight. With him aboard his aircraft was copilot Major Brian G. McAvoy, Fleming, and an Air Force master sergeant. The route took them out of Goose Bay, Labrador, to a point 80 miles off the southern tip of Greenland, from which they headed south to make landfall. Three 130s accompanied them on the Atlantic flight. "We flew a loose formation, .2 or .3 nautical miles off [the Herks]," says Lane. Both aircraft experienced compressor surges, or stalls, marked by temperature spikes, but Lane's was mild, and he continued on to England after the second Osprey, plagued by a more persistent compressor stall problem, diverted to Iceland. Lane describes the diversion as precautionary. Cruise speeds varied, but mostly ranged between 200 to 215 knots (230 to 250 mph).

For these Marines, the flight was memorable in many ways. "I'd never seen icebergs before," Lane says. And theirs was the first Osprey to cross the Atlantic. "The first of many," adds Lane.

GEORGE C. LARSON, MEMBER, NAA

LOGBOOK

Public Benefit Awards

The National Aeronautic Administration recently announced the winners of this year's Public Benefit Awards, a series of awards recognizing those in aviation engaged in humanitarian efforts.

Ted Ruscitti of Pennsylvania was honored as the Distinguished Volunteer Pilot. The Distinguished Volunteer Award went to Jubel Caldwell of Mercy Med+Flight in Texas.

The Outstanding Achievement in the Advancement of Public Benefit Flying Award went to "All Volunteers and Organizations Who Served the Nation During a Time of Need," in honor of the thousands of volunteers who devoted time to victims of Hurricanes Katrina and Rita.

Remote Area Medical and Wings of Hope shared the Public Benefit Flying Teamwork Award for their partnership, established in 1995. The Champion of Benefit Flying Award was presented to all air traffic controllers who support public benefit flying.

Continental Airlines will also be honored with the Champion of Public Benefit Flying Award for their support of public benefit flying over the past 12 years.

NAA National Aeronautic Association

Moments & Milestones is produced in association with the National Aeronautic Association. Visit the NAA Web site at www.naa.aero or call (703) 527-0226.